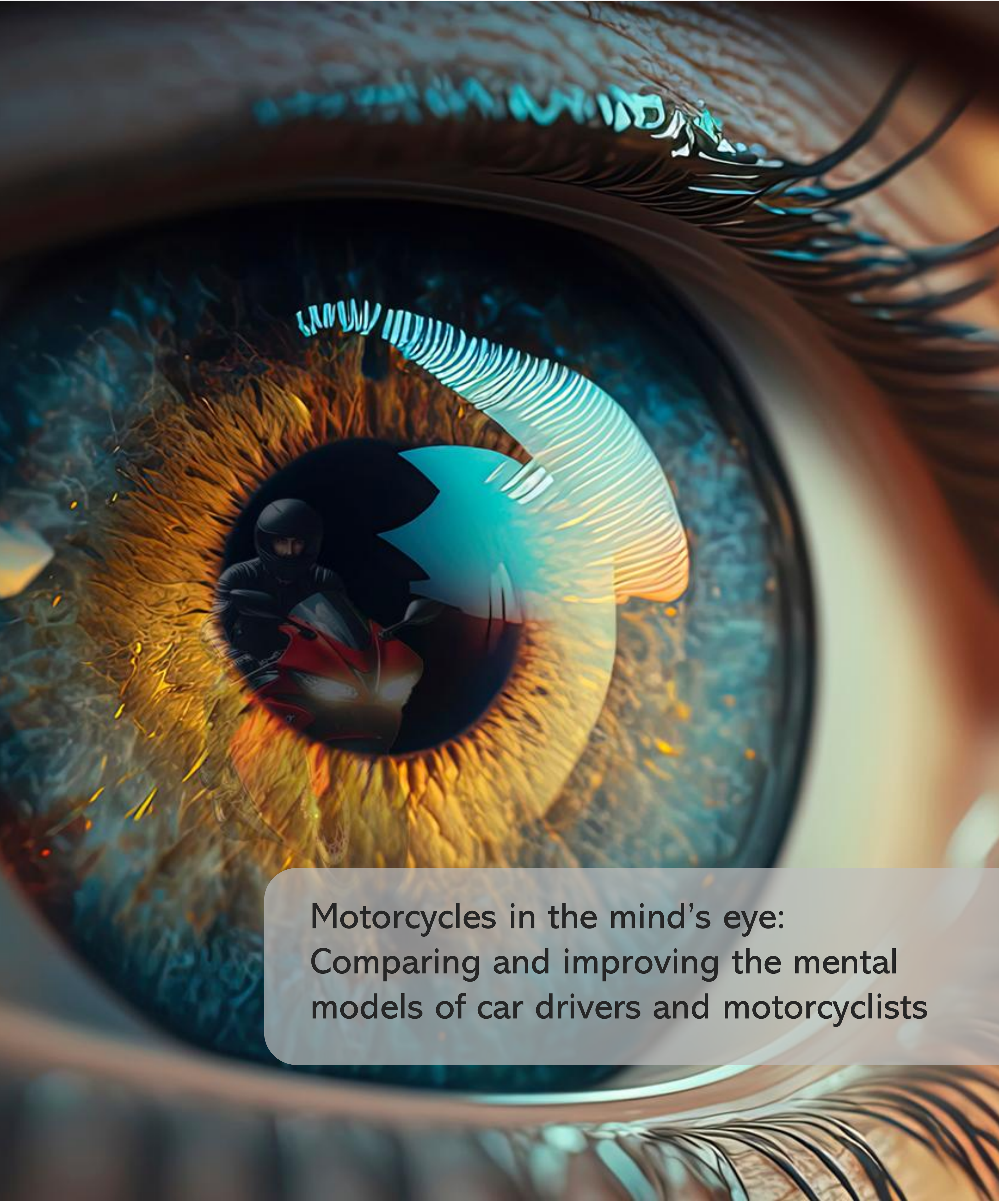

Motorcycles in the mind's eye: Comparing and improving the mental models of car drivers and motorcyclists

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Motorcycles in the mind's eye:

Comparing and improving the mental models of car drivers and motorcyclists

David Crundall, Editha van Loon

and Megan Hutchinson

Nottingham Trent University

50 Shakespeare Street

Nottingham, NG1 4FQ

Executive Summary

1. Motorcyclists are disproportionately injured and killed on UK roads. They represent less than 1% of traffic, yet nearly 20% of fatalities. Many collisions involve other vehicles where the other road user is found at fault. We need more evidence-based interventions to reduce this inequality.

2. Motorcyclists and car drivers can view each other as members of an 'out-group' and therefore find it easier to attach negative attitudes and stereotypes to each other. Such negative attitudes may distract from safe riding or driving. Drivers can feel less obliged to take care around motorcyclists if they believe that such riders take undue risks, while motorcyclists may attribute any near collisions to the carelessness of drivers, reducing their motivation to change their riding behaviour to avoid future collisions. If we can mitigate these out-group biases, we can potentially improve both car drivers' and motorcyclists' safety in the future.

3. One way to tackle negative perceptions between road user groups is to provide evidence-based explanations about the causes of car-motorcycle collisions, emphasising the impact of natural psychological biases that arise primarily due to car drivers' lack of experience of motorcycles. Such lack of experience leads to inaccurate *mental models* of how motorcyclists might behave, and the locations they might appear from on the road. Such fact-based explanations can dilute the negative attributions that riders and drivers apply to each other by increasing empathy for the difficulties that they face on the road, and potentially improving the way they interact in the future.

4. Our first study attempted to identify a suitable scenario where natural biases impact drivers' ability to spot and respond appropriately to motorcycles, which could then form the basis of an evidential intervention to change negative perceptions between these two road user groups. We asked car drivers and *dual drivers* (those who both drive cars and ride motorcycles) to watch four hazard perception clips from the perspective of a car driver, each containing a motorcycle hazard. Four non-motorcycle hazard clips were also shown as decoys. These clips were designed with computer-generated imagery and were presented in a VR-headset, so participants had the full 360-degree driver's perspective to explore.

5. One of the four motorcycle hazard clips showed a clear difference between our car drivers' and dual drivers' ability to spot the motorcycle. The clip showed a driver pulling up to a T-junction intending to turn right. There was stationary traffic on the main carriageway from right to left, and infrequent traffic from left to right. As the car moves through a gap in the traffic to turn right, a motorcycle passes them while overtaking the standing traffic from the right. Our car drivers did not expect any threat to come from the right as the line of cars was stationary, and instead focused exclusively on the infrequent traffic from the left. Our dual drivers responded to the approaching motorcyclist sooner, however. The evidence suggests that our dual drivers' understanding, and awareness of motorcycles prompted an early

examination of the road to the right, leading to an early fixation on the approaching motorcycle. This allowed them to better process and respond to the hazard. We argue that this shows our dual drivers have a more accurate *mental model* for this scenario which includes the possibility of an overtaking motorcycle. Crucially, our car drivers did not miss the motorcycle because they were inattentive, careless, or unobservant (they were in an experimental situation, ostensibly trying their best), but because they have not had sufficient exposure to motorcycles to allow them to generate more accurate mental models.

6. Using eye tracking videos of a car driver and dual driver collected from within the VR headset in Study 1, we then created two scripted videos that explained why car drivers may not spot motorcycles. These videos built on the concept of inaccurate mental models, explaining how drivers might not realise that motorcycles can appear from certain locations, and how the size, movement, and infrequency of these vehicles can lead to drivers failing to act safely. One of the videos was tailored to a motorcycling audience, and the other was written for car drivers (though the majority of the content overlapped).

7. We assessed the impact of these videos on motorcyclists and car drivers in separate studies. In Study 2, we showed our video to 78 motorcyclists. After watching the video, 91% said their understanding of the causes of car-motorcycle collisions had increased, 85% said they would change their riding behaviour accordingly in the future, and 65% said their empathy for the difficulties faced by car drivers had increased. We also collected a range of other measures both before and after the intervention (perceived safety of different road users, perceived blame for near collisions, and intended risky behaviour) in a further set of clips (e.g., "Would you overtake at this point?"). We compared scores on these measures to scores provide by a control group of similar motorcyclists (N=88). None of these additional measures showed any improvements due to the intervention video.

8. We then showed the intervention video to 71 car drivers. After watching the intervention video, 92% said their understanding of the causes of car-motorcycle collisions had increased, 88% said they would change their driving behaviour accordingly in the future, and 88% said their empathy for the difficulties faced by motorcyclists had increased. We also recruited a control group of 77 additional drivers and compared the two groups on a range of measures collected both before and after the intervention. We found that drivers who watched the intervention video rather than the control video believed they were more likely to make driving errors in the future, suggesting that the intervention made them more aware of natural biases that they could fall foul of. However, when participants were asked to identify where a hazard might appear in a CGI video taken from Study 1, the intervention group were more likely to click on the location from where a motorcycle could emerge. Thus, our intervention group have improved their ability to anticipate motorcycle hazards but have conversely seen a decrease in their confidence in avoiding such errors in the future. This, we argue, is an ideal combination of effects.

9. In conclusion, we have demonstrated that when motorcyclists drive a car, they may have a greater chance of spotting other motorcyclists, though as this effect only appeared in one

out of four scenarios, this motorcyclist-advantage may be less prevalent than previously suggested in the literature. Nonetheless, such rare scenarios might be the most dangerous when they occur on the road. Using this evidence, we created videos to persuade motorcyclists and car drivers to re-evaluate their relationship to each other, ideally resulting in safer on-road behaviour. While motorcyclists responded very positively to the intervention video regarding general future intended behaviours, the intervention had ostensibly greater impact on our sample of car drivers. Several reasons for this imbalance in effectiveness are discussed in the report ranging from practicalities (e.g., sample size limitations) to more theoretical reasons.

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1. Introduction

Motorcyclists continue to be over-represented in crash statistics. In 2023, 315 motorcyclists died, and 5,481 riders were seriously injured on GB roads. Rider fatalities accounted for 19.4% of all on-road fatalities in 2023 (DfT 2024a), yet data from the National Travel Survey suggest they travelled less than one percent of the total miles for all vehicles in the same period (DfT, 2024b). Over the last five years, total motorcycle fatalities equate to an average of 6 rider deaths and 102 serious injuries per week (DfT, 2024c), with 74% of fatal collisions involving another vehicle. The most common contributory factor was 'Driver or rider failed to look properly', followed by 'Driver or rider failed to judge other person's path or speed' and 'driver or rider was careless or in a hurry'. In previous reviews of GB collisions between motorcycles and cars, the car drivers have been found to be mostly at fault (e.g., Clarke et al., 2007).

Incompatibilities in size and speed of vehicles, such as motorcycles and cars, provide a persistent and stubborn crash-risk that is difficult to address (Elvik, 2010), but it is not just the physical properties of these vehicles that differ. Potentially of greater importance is the difference in situation awareness that users of different vehicles are likely to have (e.g., Endsley, 1995; Salmon et al., 2013; Walker et al., 2011). In a very basic sense, one's awareness of the world is, in part, dictated by what we can see at any one moment. For instance, the seating height of the driver and the variation of blind spots around vehicles of different sizes will likely result in fundamental differences in situation awareness. Thus, an HGV driver will have a better understanding of what is causing cars ahead to brake but may have less awareness of vulnerable road users who move into blind spots near the cab.

Some dangers are also more specific to some road users, resulting in differences in the way drivers of different vehicles may attend to the road ahead. Motorcyclists, for example, are more attentive to the quality of the road surface than the average car driver (e.g., Nagayama et al., 1979). This represents a generic rule, or *schema,* which motorcyclists develop but is largely absent in car drivers, as the stability of cars means that drivers need not worry about minor surface irregularities. Beyond concerns with the road surface, many other differences in schemas are likely to exist between car drivers and motorcyclists. When comparing situation awareness of car drivers, motorcyclists and cyclists, Salmon et al., (2014), found that drivers' think-aloud protocols focused on different elements of the scene (e.g., the traffic lights of a junction) while the vulnerable road users were more concerned with how other traffic might interact with them.

These mode-specific variations in situation awareness occur because our schemas are based directly on our experiences, and motorcyclists learn very quickly to keep an eye out for potholes and the behaviour of other vehicles when approaching a junction. These schemas are triggered by contextual similarity with previous experiences and help us build a mental model of the situation to guide our behaviour in terms of where we should look for danger, what the danger might look like when we find it, and how we should respond (e.g., Stanton et al., 2009).

1.1 Car drivers' inadequate mental models

Crundall, Clarke, et al., (2008) suggested that typical car drivers' mental models could cause problems for car-motorcycle interactions at several stages in the behavioural chain of events. For instance, if we consider a typical T-junction collision, where a car pulls out in front of a motorcycle on the main carriageway, we might consider there to be at least three points at which the car drivers' mental model may have failed to protect them (Figure 1): first, in whether they looked at the motorcycle; second, whether they recognised that it was a motorcycle, even after looking at it; and third, assuming they identified an approaching motorcycle, whether they appropriately appraised the risk it posed (how far away is it? How fast is it travelling?). The schemas underlying the driver's mental model are built on prior experience of similar T-junctions (and possibly multiple experiences of that very T-junction), which can influence attitudes, skill, and strategies for dealing with similar situations in the future (though experiences can also be interpreted through the lens of current attitudes, skills and strategies). These *top-down* factors, in turn, influence the development of schemas, which then interact with, and sometimes compete with, bottom-up factors such as visual saliency to direct our behaviour.

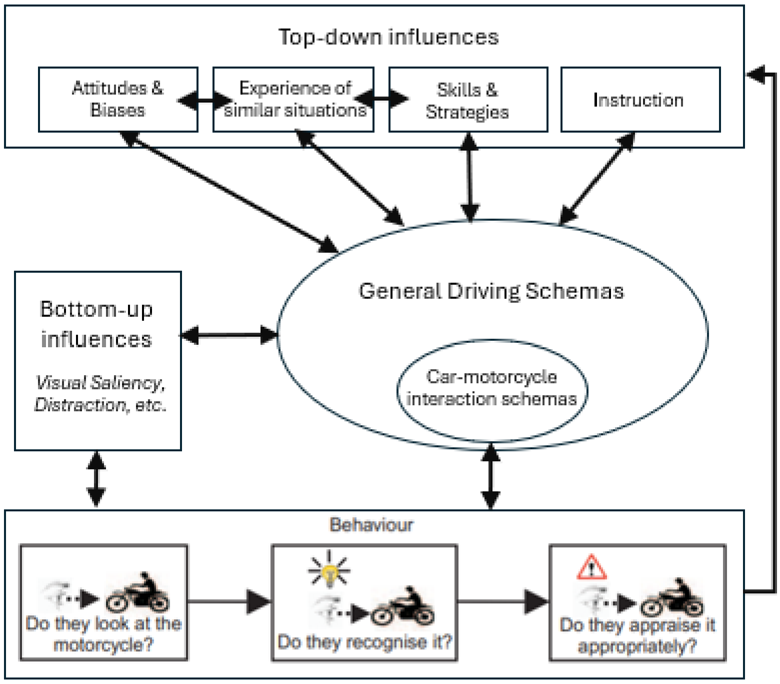


Figure 1. A framework describing the factors that influence the detection, discrimination, and appraisal of a motorcycle (adapted from Crundall, Clarke, et al., 2008).

As this T-junction example is one of the persistent causes of car-motorcycle collisions, it suggests that many drivers have not optimised this particular schema. This is understandable, as optimal schemas are naturally developed across many experiential instances. Given that motorcycles make up less than 1% of traffic in the UK, most drivers do not have the opportunity to naturally develop schemas that accommodate these VRUs. This is notable in previous comparisons of motorcyclists and car drivers on tasks that involve spotting motorcycles. For instance, Crundall et al., (2012) provided drivers (half of whom also rode a motorcycle, and were labelled *dual drivers*) with a 180-degree video across three screens showing the approach to a T-junction. Participants were required to press a button when they thought it was safe to pull out. Some of the clips showed empty junctions where an immediate response was acceptable. Other clips contained approaching cars or motorcycles. The dual drivers did not look at an approaching motorcycle any faster than the ordinary drivers, but they remained looking at the motorcycle for longer, and thus made safer button responses. The authors suggested that eye movements of their (non-motorcycling) car drivers reflected a 'Look But Fail To See' error (Brown, 2002): in some instances, the car drivers looked directly at the motorcycle, but then looked away and pressed the button as if they had not seen it at all. In contrast, the dual drivers had more experience of motorcycles, and therefore presumably had a lower perceptual threshold for identifying a motorcycle. This allowed them to recognise the approaching danger (indicated by longer gazes on the motorcycle) and make safer responses.

If we accept that exposure leads to the development of better schemas (e.g., Salmon et al., 2013) and therefore better mental models, then drivers who live in areas of the country with higher numbers of motorcyclists should be safer. This 'safety in numbers' hypothesis has received support from a number of researchers (e.g., Beanland et al., 2014; Jacobsen, 2015). For instance, Lee et al. (2015) compared Malaysian and UK drivers on a motorcycle detection task. Following a methodology used by Crundall, Humphrey and Clarke(2008), they showed brief junction pictures that were either empty or contained an approaching car or motorcycle. Based on the huge amount of motorcycle ownership in Malaysia (with over 13 million motorcycles in a population of 34 million people, compared to 1.3 million motorcycles across a population of 68 million in the UK[1]) the authors predicted that Malaysian drivers would be better at spotting motorcycles than UK drivers. This result was confirmed, though in a second study Malaysian drivers were found to be more willing to pull out in front of these approaching motorcycles. This result highlights the paradox of exposure: while increased exposure may lower the threshold for detecting future instances of the same stimuli, it can also desensitise one to the threat these stimuli pose (e.g., Ventsislavova et al., 2019).

In situations where natural exposure to motorcycles is infrequent, we must turn to other methods to encourage development of appropriate schemas. We can provide vicarious experience of motorcycles through exposure to videos of scenarios, which is essentially the rationale behind the hazard perception test: sufficient practice builds up hazard perception schemas which should improve the visual search of drivers for hazards (e.g., Kahana-Levy, et al., 2019). Alternatively, we could have drivers make repeated categorical decisions about motorcycle pictures (e.g., using a motorcycle Pelmanism game; Crundall et al., 2017), which has been found to lower the threshold of future identification for motorcycles in road scenes. A third option is to consciously influence schemas through explicit instruction. For instance, implementation intentions (Gollwitzer, 1999) refer to a technique where participants are encouraged to make explicit links between the situation and their desired behaviour (e.g., *if* I am passing a school, *then* I will slow to 20 mph). The theory suggests that if these conscious rules are followed diligently for long enough, they will become automatic. This essentially describes the use of conscious information to modify schemas. The evidence for implementation intentions to influence a range of behaviours is considered so strong that the activity of creating '*if X then Y'* statements is now fundamental to all UK diversionary courses provided through the National Driver Offender Retraining Scheme.

1.2 In-groups and out-groups

Some road user groups can hold irrational negative views about other road user groups (e.g., Crundall, Bibby, et al., 2008; Crundall and van Loon, 2023). This reflects an in-group bias, where people perceive those who are part of their 'group' more positively. We understand the minds of in-

[1] https://www.worldatlas.com/articles/countries-that-ride-motorbikes.html

group members, we empathise with their pain, and we gain neurological rewards when in-group members triumph over out-group members (Molenberghs and Louis, 2018; Gatersleben and Haddad, 2010). The 'group' does not need include friends or family; anyone with whom you perceive to share a core element of your personality might be considered part of the in-group, including people who support your favourite sports team, or perhaps even people who drive the same car as you.

Conversely, anyone who is overtly linked to something in which you have no interest is likely to be placed in the out-group. Individuals in the out-group are easy targets for negative attitudes and thoughts, and the activation of negative stereotypes, especially when there is conflict between the two groups (e.g., Abbink and Harris, 2019), such as different road users vying for the same space.

Just as car drivers hold negative views of motorcyclists (e.g. Crundall, Bibby, et al., 2008) so motorcyclists can hold negative views of drivers. When questioned about the cause of car-motorcycle collisions, motorcyclists will often identify car drivers as the cause (especially less experienced motorcyclists, Crundall et al., 2013), often citing causes such as the 'carelessness' of drivers, or their 'poor observation' (Robbins, et al., 2018). Such negative attitudes towards other road user groups can impede safe behaviour through distraction via negative emotion, or through a 'teach-them-a-lesson' mentality (Lennon and Watson, 2011; Piatkowski et al., 2017). For instance, riders might attribute a range of negative qualities to drivers who fail to spot a filtering motorcycle, but this can be counterproductive to safe riding as negative emotions can delay avoidance responses in the face of a hazard.

Admittedly, drivers do make visual errors, but many of these errors, such as the 'Look But Fail To See' error, are not necessarily due to driver ignorance, arrogance, distraction, or any other negative label that riders might apply. Rather they occur as biproducts of the normal functioning of the visual system in non-normal (uncommon) situations, such as when a driver is faced with an approaching motorcycle (Wolfe et al., 2022). Due to out-group discrimination, these side-effects of visual processing are negatively attributed to the personality of the other road user or skill failures.

There are however a range of techniques by which researchers can bring out-group members closer to the in-group. For instance, empathy evoking videos (showing the 'real people' behind the labels of *horse riders* and *cyclists*; Crundall and van Loon, 2023) or perspective taking exercises (letting one road user group experience the dangers faced by a road-user out-group; Shahar et al., 2011) have both been found to improve attitudes to out-group members. In the context of car-motorcycle collisions, there is perhaps a much easier manipulation. By explaining the biases of the human visual system, we might be able to directly change the views that motorcyclists and car drivers have of each other. Our framework (Figure 1) suggests that such instruction might influence schemas, which may then help create a safer mental model of an anticipated car-motorcycle interaction. We consider this possibility in this study.

1.3 The current study

The current study had a number of aims. In study 1, we intended to confirm whether hypothesised differences in car drivers' and motorcyclists' mental models of certain hazardous situations could be identified by analysis of their eye movements and response times to hazards. Following, Crundall et al. (2012), we predicted that *dual drivers* (car drivers who also ride motorcycles) would be better at identifying motorcycle hazards than ordinary car drivers in a series of hazard perception clips. This may reveal itself in how quickly our dual drivers fixate motorcycle hazards, or how long they process (or gaze at) them, which may in turn relate to when they make a hazard perception response. While Crundall et al. (2012) did not find a dual driver benefit in the time taken to first look at a motorcycle hazard (only finding an effect of gaze duration on the hazard), they used very simple hazards (an unobstructed motorcycle travelling down the main carriageway towards the participant). Instead, for this study we intended to use more complex scenarios where participants might be surprised by the appearance of a motorcycle if they do not appreciate the manoeuvrability of these vehicles (such as a motorcycle overtaking a line of static or slow-moving traffic, Robbins et al., 2018). Following advances in hazard perception testing (e.g., Crundall, van Loon, et al., 2021) we also intended to produce our clips using computer-generated imagery (CGI), to allow for the precise manipulation of complex scenarios, and present these in a full 360-degree field of view via a VR headset.

Once we had found differences in the mental models of drivers and motorcyclists, our second aim was to use this evidence to explain to both car drivers and motorcyclists why such collisions might happen. The rationale for this approach is that the provision of evidence (i.e., eye tracking videos of the hazard clips that provide clear examples of these natural errors) will support our argument that these collisions or near-collisions are caused by inherent psychological biases. We packaged the evidence into two videos and showed them to motorcyclists (Study 2) and car drivers (Study 3) with the prediction that, compared to control groups, our participant groups' attitudes towards each other will become more tolerant, and that both road user groups will acknowledge the need to behave more safely in typical situations where cars and motorcycles can come into conflict.

2. Study 1

2.1 Introduction

The aim of the first study was to investigate whether *dual drivers* are more likely to spot motorcyclists than car drivers are, which would be indicative of a safer mental model. We used six existing CGI 360-degree clips that were developed for a previous project (Crundall, van Loon, et al., 2021) and designed two new clips. Of these eight clips, four involved a motorcycle hazard, and four involved a pedestrian or car-based hazard. The four motorcycle clips involved a motorcycle appearing from locations that varied in the level of surprise they might evoke (following Crundall et al., 2012) in the average car driver. We predicted that our dual drivers might fixate these motorcycles earlier than our ordinary car drivers and that their gaze durations may also indicate greater processing. We also expected one, or both, of these eye movement indicators to influence the speed with which our dual drivers responded to the hazards via a button press.

While there was a possibility that the motorcycle experience of our dual drivers might produce an overall omnibus effect, we were aware that some of our motorcycle clips might be more successful than others in finding this effect. For example, one of the clips involved a motorcycle appearing from behind an HGV while the 'ego car'[2] is turning right at a crossroads (see Figure 2). All safe drivers

[2] The term 'ego car' is often used by researchers to refer to the vehicle from whose perspective we present a hazard perception clip.

should be looking at the HGV as they pass it, as any vehicle might emerge from this location to cause a hazard (i.e., the motorcycle could be replaced with a car, and the hazard would be equally valid). Contrast this with another clip where our car is trying to turn right at a T-junction; there is standing traffic from right to left (though with enough gap for us to pass through when turning right), and infrequent traffic from left to right. The hazard in this case is a motorcycle that overtakes the standing traffic while also travelling from right to left at the same time as we try to pull out. In this case, typical car drivers have a strong interest in looking to the left, and presumably little interest in looking to the right as the standing traffic ostensibly precludes any threat from that direction. In this clip, we might expect the mental model of the dual drivers to include the possibility of an overtaking motorcycle. This latter clip will likely be more successful in demonstrating an advantage for our dual drivers than the former (see Figure 2).

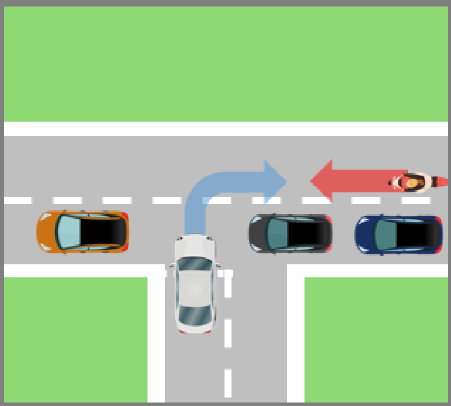
Figure 2. Screenshots showing two of the developed motorcycle hazards. The motorcycle hazard in the left panel (a motorcycle appears from behind an HGV) is arguable less likely to surprise car drivers than the hazard in the right panel (a motorcycle overtakes standing traffic while you turn right from a side road).

2.2 Method

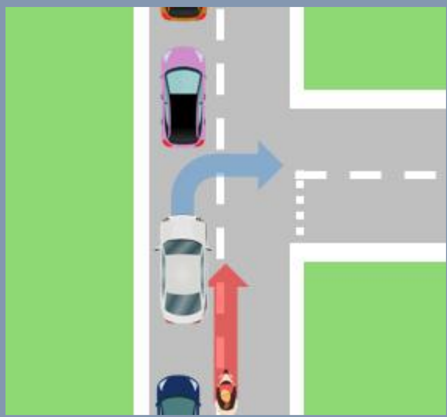
We recruited 121 participants who identified as either car drivers (N = 61, 11 female, mean age 44) or dual drivers (car drivers who also ride motorcycles; N = 66, 11 female, mean age 50). Data cleaning removed 17 participants due to technical issues, cybersickness, or failure to follow instructions.

All participants viewed eight clips in a VR headset and pressed a button as quickly as possible when they saw a hazard. Four of the clips had motorcycles as hazards (Figure 3). The four non-motorcycle hazard clips included three car hazards and one pedestrian hazard.

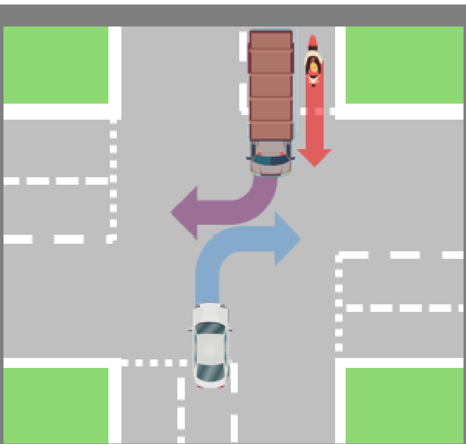
We converted participants' response times into scores based on the DVSA scoring system for the national Hazard Perception Test. Scoring windows were created around the hazards. These windows were then split into five segments of equal duration. Responses in the first segment were awarded five points, with responses in subsequent sections awarded a decreasing number of points until the scoring window closed. We also recorded participants' eye movements via an eye tracker that was built into our VR headset.



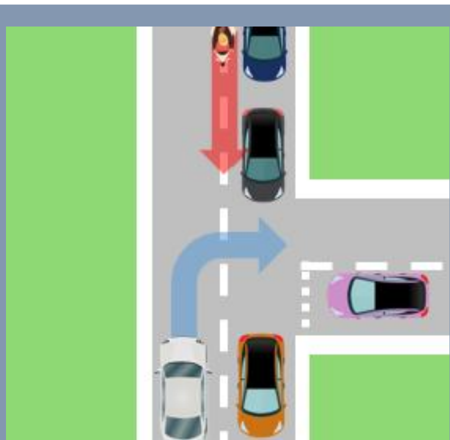
M1. You are turning right. Traffic is queuing on the main carriageway from the right. There is infrequent traffic from the left. A motorcycle from the right overtakes the standing traffic as you pull out.



M2. While queuing in traffic, you decide to turn into a side road to avoid the congestion. A motorcycle overtakes you as you begin to turn.



M3. At a traffic-light controlled crossroads you view of oncoming traffic is hidden by a turning HGV. As you begin to turn, a motorcycle emerges from behind the lorry.



M4. You want to turn into a side road on your right in-between queuing vehicles. As you turn, an oncoming motorcycle overtakes the standing traffic.

Figure 3. A schematic view and description of the four motorcycle hazards used in Study 1.

Prior to the study, participants were asked a series of demographic questions to ascertain their age, gender, and their driving and riding history. At the end of the study, they were also asked to fill in a questionnaire. This included eight questions probing their propensity to commit driving errors and eight questions to assess how often they violate road rules (taken from the Driver Behaviour Questionnaire, e.g., Lajunen et al., 2004). We included an additional six items related to the perception of, and behaviour towards, motorcyclists (adapted from Crundall, Bibby, et al., 2008). We call this our *motorcycle awareness* scale. A more detailed methodology for Study 1 can be found in Appendix A.

2.3 Results

First, we looked at the questionnaire data. There was no difference between the DBQ error and violation scales across our two groups, but we did find a difference in *motorcycle awareness.* On a scale of 0-5, our car drivers gave an average score of 2.92 compared to our dual drivers' average score of 3.75 ($t = -6.20$, $p < .001$). This reflects the greater awareness that dual drivers have regarding motorcyclists.

We then compared the summed hazard perception scores for the four motorcycle-hazard clips and the four non-motorcycle clips, across the two groups. With a maximum possible score of 20 points, we found the motorcycle-hazard clips to be a lot harder than the other clips (10.0 vs. 13.5 points, respectively; F (1,102) = 67.75, $p < .001$), but there was no difference in scores between our two groups at this level of analysis.

However, we expected some of the clips to be more effective at showing a dual driver benefit than others, so we then compared our two groups across each individual clip. We found a significant difference for one of our motorcycle-hazard clips (clip M1; see Figure 3), with dual drivers scoring more points than our car drivers (with 2.4 vs. 1.7 points, respectively, out of a possible total of five points; $t = -2.27$, $p < .05$).

This clip also showed differences in eye movements across the two groups. Dual drivers looked at the motorcycle hazard more than a second earlier than the car drivers on average ($t = 2.72$, $p < .01$) and looked at it for nearly half a second longer than car drivers ($t = -2.29$, $p < .05$).

Regression analyses suggested that the amount of time that participants spent looking at the motorcycle hazard (*dwell time*) predicted their subsequent hazard score (and this held across all of our motorcycle clips). Subsequent regressions found that *dwell time* was in turn predicted by how quickly participants looked at the motorcycle hazard, with earlier fixations of the hazard allowing longer time to remain looking at it. For clip M1, the time taken to first fixate the motorcycle hazard was in turn predicted by participants' scores on the *motorcycle awareness* scale that they filled in. Thus, for clip M1 it appears that greater motorcycle awareness helps participants to spot the motorcycle hazard quickly, which then affords them more time to look at it, decide whether it is a hazard, and then score more points with a quick response. A more detailed results section for Study 1 can be found in Appendix A.

2.4 Discussion

Results showed that for most of the motorcycle clips used in the study, hazard performance and eye movement behaviour was similar for car drivers and dual drivers. However, one of the clips that featured a motorcyclist overtaking past a line of standing traffic did differentiate between the two groups. Dual drivers spotted the motorcyclist sooner, spent more time looking at it, and were subsequently faster to respond when it became a hazard. Regression analyses suggested a chain of interrelated behaviour with increased motorcycle awareness resulting in drivers fixating the motorcycle hazard earlier. This, in turn, provided them with the opportunity to look at the motorcycle hazard for longer, presumably increasing the chance of realising that it posed a threat, leading to faster responses. This chain of prediction supports the hypothesis that the mental models, and schemas that underlie them, differ between our two groups dependent on motorcycle awareness.

Why did the other three motorcycle hazard clips not show any dual driver benefits? The answer may lie in the level of surprise that the appearance of the motorcycle was likely to induce (as noted in the introduction). In clip M1, the average car driver is likely to be looking to the left as they pull out of the junction. Understandably, their mental models do not include the possibility of danger appearing from the right, so when it does, it typically came as a surprise. Conversely, M3 has a motorcycle appear from behind an HGV as the ego-car turns at a junction. Arguably, all experienced drivers should be watching the leading edge of the HGV for *any* vehicle that might emerge suddenly. Thus, there is likely to be little benefit in knowing where to look for a motorcycle hazard *per se*, as any vehicle that appeared from this location would have posed a threat. We might still argue that our dual drivers should have a lower threshold for identifying motorcycles, and therefore should still respond faster than car drivers. However, our car drivers do not need to realise that it is a motorcycle in this clip. They can simply respond based on sudden movement from a threatening location, well before they even realise that it is a motorcycle.

A lack of dual driver benefits in clips M2 and M4 are a little harder to explain, as the manoeuvres shown by the motorcycle hazards are very specific to riding (both including riders overtaking lines of stationary traffic). Unlike M1 however the motorcyclist still appears from areas of the scene that our car drivers have good reason to look at. In M2, as the ego-car prepares to turn right, it is natural for drivers to look in their side mirror; perhaps the well-learned mantra *mirror, signal, manoeuvre* provided the necessary safety net. In M4, the motorcyclist hazard appears from directly ahead of the film car. In both clips it is possible that our car drivers looked at the motorcyclists simply because they have learned to look in these locations for general driving purposes (rather than for the specific reason of searching for motorcyclists).

While we must take care with post-hoc rationalisation, it does appear that clip M1 caused a perfect storm of misleading cues. Drivers understandably felt impelled to look to the left to ensure the way was clear, and they had no reason to think that danger might come from the right. While some drivers did miss the hazard on the other three motorcycle hazard clips, M2, M3 and M4 all contained reasons for drivers to be looking in the general direction from where the motorcycle hazard appeared. This may have acted as a safety net for drivers who would have been otherwise let down by a mental model that did not include motorcycle hazards. It is possible that the speed with which the motorcycle overtook the standing traffic in clip M1 (30mph) contributed to the surprise, as most riders would adopt a slower speed in such circumstances. However, the speed of the motorcycle makes it all the more impressive that our dual drivers were able to spot and respond faster than our car drivers.

One might question whether the motorcyclists' behaviour in M1 contributed to our participants' performance. The particular manoeuvre (overtaking traffic in the oncoming lane) could be considered risky behaviour, especially in proximity to a side road. However, in mitigation, motorcycles are legally allowed to overtake standing traffic (though a lower speed would be advisable in such scenarios), and riders may be unaware of side roads until they pass them. Furthermore, the motorcyclist behaviour in clips M2 and M4 is identical to that in M1; only the car driver's perspective changes. Regardless of the blameworthiness of both actors in this scenario, the clip reflects a real-world problem that needs addressing.

The failure of the other clips to show a dual driver benefit could be taken to suggest that dual driver benefits might be less prevalent in the real world than suggested in the literature (Magazzù et al., 2006, Crundall, Bibby, et al., 2008) and require an alignment of factors. However, even though such events might be relatively rare, they are likely to be the most dangerous when they occur. On this basis, we recommend researchers explore further scenarios that may demonstrate a dual driver advantage.

3. Study 2: Motorcycle intervention study

3.1 Introduction

Study 1 found evidence for different mental models of motorcyclists and car drivers in a scenario where a motorcyclist was overtaking a line of stationary traffic, while our driver was emerging from a side road. Admittedly, the finding was not as robust as expected, with the remaining clips failing to show a dual driver benefit. Nonetheless, M1 demonstrates that when events conspire against us, it is possible to have a situation where car drivers' lack of exposure to motorcycles may contribute to crash risk. Indeed, when one observes the eye-tracking videos of our car drivers and dual drivers, this difference is noticeable to the naked eye, and potentially provides a powerful piece of visual evidence that could make both car drivers and motorcyclists rethink these types of interactions for the future.

Studies 2 and 3 were therefore designed to assess whether these eye-tracking videos, scaffolded by appropriate training messages, could influence the way that car drivers and motorcyclists perceive each other, and the dangers involved. We have already reviewed evidence to show that motorcyclists have negative views of car drivers, and vice versa, and it is possible that such negative thoughts can distract from safety and lessen the personal responsibility that they feel for reducing the risk of a crash. If we can weaken such out-group bias and increase awareness and understanding of why such car-motorcycle collisions occur, then this may improve the chances of both road user groups' avoiding such situations in the future.

Study 2 focused solely on improving the attitudes and understanding of motorcycle riders using an intervention group and a control group. While eye tracking videos have been used as part of training interventions in the past (Konstantopoulos, Chapman & Crundall, 2012), this has always been to train drivers in where to look, rather than the current aim, which is to explain why drivers have problems in spotting motorcycles. Additional activities and explanations were also included, with the final video lasting nearly 15 mins.

We chose four different methods for assessing whether the video changed the attitudes, understanding, or behaviour of our intervention group. First, we asked them how safe they thought the average car driver and motorcyclist is (along with several other road user groups). Secondly, we devised a *blame test.* This is a novel task, based on findings from Crundall et al. (2013), where participants watch video clips from the rider's perspective. A hazard occurs, typically involving a car, and then our motorcyclist participants are simply asked who was to blame for the near collision (i.e., either the motorcyclist or the other road user). The 2013 study found that advanced riders had a more nuanced interpretation of these hazards, often arguing that the behaviour of the motorcyclist contributed to the danger. Less experienced riders were more likely to wholeheartedly blame the car drivers for the hazards. We argue that the shift in blame noted with rider expertise represents a mitigation of out-group bias that is predicated on a reduction of in-group alignment (i.e., advanced riders no longer see themselves as 'part of the pack'). Accordingly, we anticipated that we might see a similar shift in blame for those riders who are exposed to our training video.

As a third measure of potential training impact, we created a series of video clips that required riders to make decisions about immediate behaviour (e.g., what speed to take around a particular bend, whether or not to overtake in certain situations, etc.). We have called this the *risk test.* These clips involved potential scenarios that relate to the issues covered in the training videos (e.g., one overtaking clip showed a car in a side road waiting to pull out, mirroring a scenario covered in the training video). We predicted that those riders who saw the intervention video would give safer responses (e.g., slower speeds around blind bends, a reduction in willingness to overtake while passing a side road, etc.).

Finally, we asked our participants directly whether they thought the video had improved aspects of their knowledge, attitudes and future intended behaviours. We predicted that exposure to our intervention video would improve one or more of these measures compared to responses given by the control group.

3.2 Method

We recruited 166 motorcyclists who were allocated to either an intervention group (N = 78, 23 female, mean age 43) or a control group (N = 88, 21 female, mean age 43). The online study consisted of two parts. The first was a pre-intervention battery of tests to assess participants' baseline responses. One week later, participants were exposed to either the intervention video or a control video, which was followed by a re-run of the test battery to check for immediate changes in participant responses. At the end of the study, we also asked them a series of direct questions regarding their thoughts on the video (e.g., "Did the video increase your understanding of why car drivers might crash with motorcycles?").

The test battery had four components:

1. We asked our riders to report their *perceived safety* of car drivers and motorcyclists on 7-point scales from *very unsafe* to *very safe*
2. Our *blame test* consisted of ten clips filmed from a motorcycle showing real-life hazardous incidents. Riders were asked to apportion blame to either the rider or the other road user involved (a car driver) using a percentage sliding scale ranging from *motorcyclist completely*

to blame (0%) to *car driver completely to blame* (100%). A second question asked whether the incident was due to an error of judgement or a wilful violation (with *error* at 0% and *wilful violation* at 100% on the scale).

3. A *risk test* consisted of seven video clips that asked riders to make decisions (e.g., 'At what speed would you take this bend?', 'Would you overtake in this scenario?').
4. *Video evaluation* questions were only given to riders in the intervention group in the post-intervention battery. These questions asked whether the intervention video increased their 'understanding of why cars crash into motorcycles', increased their 'empathy for the difficulties that car drivers face when interacting with motorcycles', and whether the video 'will change the way I ride a motorcycle in these situations in the future'.

The intervention video for motorcyclists was just under 15 mins long and used eye tracking videos from Study 1 to explain why car drivers might miss motorcycles in certain situations. The video narrative was based on three behaviours noted in Figure 1 (*look, recognise, appraise*). The control video was nearly 9 mins long and was concerned with the dangers of hands-free phone calls (and thus unrelated to motorcycle safety). The procedure of the Study can be viewed in Figure 4, while screen shots of the intervention video can be found in Figure 5. A more detailed methodology for Study 2 can be found in Appendix B.

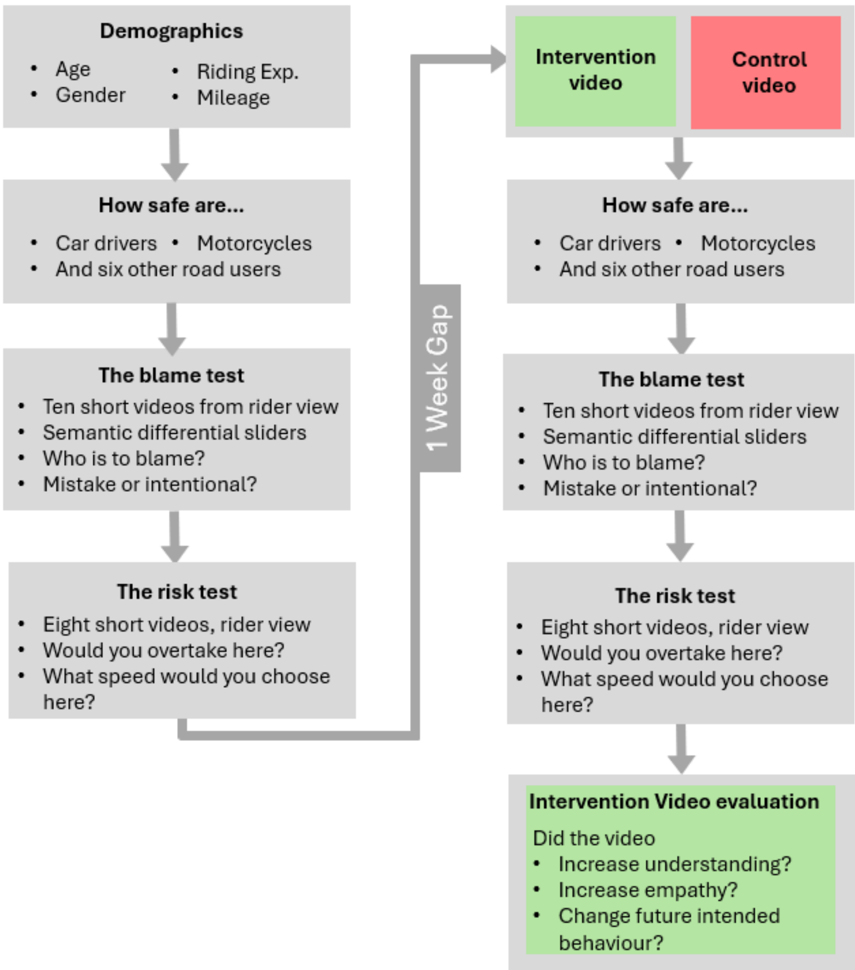


Figure 4. A diagram showing the blocks in the pre-test (left) and post-test (right).

Figure 5. Screenshots of the intervention videos.

3.3 Results

Analysis of the motorcyclist and car driver *perceived safety* ratings found our riders to rate motorcyclists as safer, suggesting a small but significant in-group bias. Regarding the blame test, our riders were more likely to blame the incident on the actions of the other car driver than on the motorcyclist. Neither of these measures were influenced however by exposure to the intervention video.

Responses to the *risk test* were remarkably conservative, with low number of respondents reporting that they would overtake in our scenarios. They also gave relatively slow speed intentions for our bend clips and our overtaking (circa 26 mph and 21 mph, respectively). Given that these *risk test* measures were so low, it was unsurprising to find no change in these responses following exposure to the intervention video.

Despite the lack of effects in the majority of the battery, when our riders were asked directly whether the intervention video had any positive benefits in terms of their understanding, empathy and future intended behaviours, the majority of riders reported improvements (with 91%, 65% and 85% recording varying levels of agreement with improvement in our three measures, respectively; see Figure 6). A more detailed results section for Study 2 can be found in Appendix B.

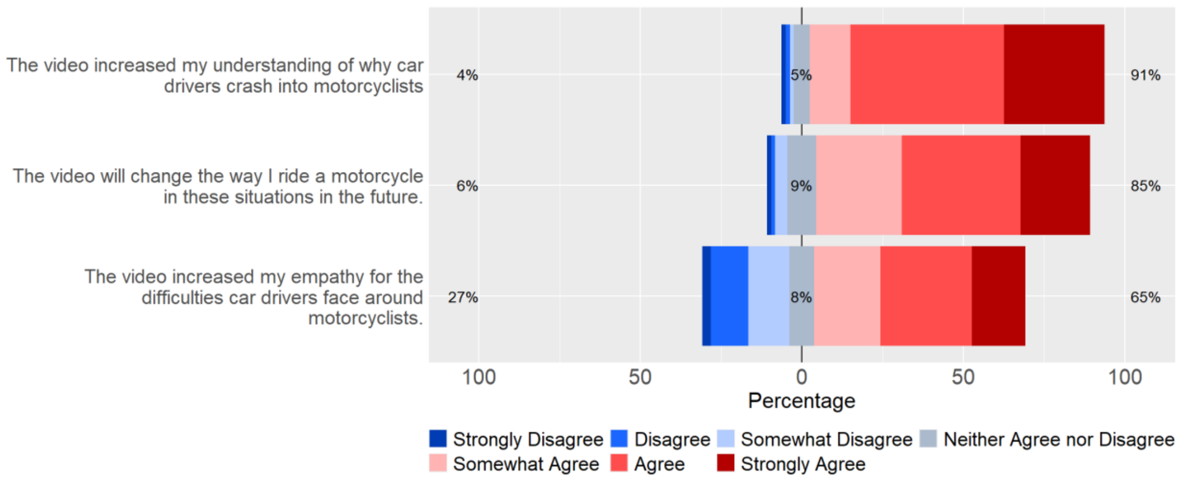


Figure 6. Riders' agreement with belief statements regarding the intervention video. Numbers reflect the percentage of the sample who disagreed, were ambivalent, or agreed with the statements (from left to right).

3.4 Discussion

The evaluation found very high agreement among our sample of motorcyclists that their understanding of the causes of car-motorcycle collisions had increased, and that the video will change the way they ride in the future. The majority of riders also agreed that the video had increased their empathy for the difficulties that drivers face when trying to spot and respond appropriately to motorcycles.

Unfortunately, none of the other measures showed a benefit of the intervention. We hypothesised that increased empathy (which 65% of our sample claimed to have) would shift the balance of blame. While our motorcyclists ostensibly demonstrated in-group bias prior to the intervention (with greater blame apportioned to the car driver on average) the mitigation of this bias was not forthcoming in the post-intervention condition.

It is possible that our clips simply showed events that were too obviously due to the fault of the car driver, and thus no amount of increased empathy will change their attribution of blame. In defence of the test however, cases could be made for some motorcyclist responsibility in almost all of the clips. For instance, in one clip, a car ahead suddenly brakes causing a hazard. While this behaviour might be judged to be the blameworthy cause, one could also argue that the motorcyclist was travelling too close. Similarly, in a clip where a car pulls out from a concealed junction, the motorcyclist could arguably be criticised for riding too fast. Other clips show the motorcyclist looking at a mobile phone prior to the hazard, or spending too much time in the blind spot of a car on the roundabout. We are not claiming that these motorcyclists *are* at fault in these instances; we are merely pointing out that there are potential reasons to reconsider the apportion of blame. Similarly, there was no change in reported behaviour in the risk test, though reported speeds for bends and overtaking were conservative, and thus this may have reflected a floor effect.

An alternative explanation for the lack of effects in the risk and blame tests might be that, while our riders agree that they have greater understanding and empathy, and will change their behaviour *in general*, this doesn't translate to our specific examples. This does not mean that riders will never change their behaviour in any future specific situations based on the intervention video, it simply means that we haven't identified or adequately recreated those situations where it might change.

4. Study 3: Car driver intervention study

4.1 Introduction

The results of Study 2 suggested that motorcyclists were explicitly receptive to the information contained in the video, yet their responses to the perceived safety of road users, the blame test, and the risk test did not show benefits of exposure to the training video. The next step was to assess whether the video has any impact on car drivers.

When cars and motorcycles are involved in a collision it is typically the car driver who is found at fault (e.g., Clarke et al., 2007), therefore arguably there is more scope for change with the car drivers. By explaining the natural psychological biases behind causes of such collisions, we hope to change the way car drivers behave when similar situations arise. For instance, if we can make car drivers think about the possibility of an approaching motorcycle while waiting to pull out from a side road, then we may prevent a 'Look But Fail To See' collision.

The motorcycle intervention video was re-edited slightly to make it more appropriate for car drivers, and we altered the pre-post assessment blocks to better fit with our new sample of car drivers. While we kept the blame test, we removed the risk test as it would be irrelevant to ask car drivers how they will behave on a motorcycle. This provided the opportunity to include the adapted DBQ (including the Motorcycle Awareness items) at both the pre- and post-intervention phase. We also introduced a *hazard location task* created using a motorcycle-hazard CGI clip taken from study 1. The clip froze before the hazard appeared and participants were asked to click on areas of the scene where a hazard might appear from.

Across all our measures, we predicted that the intervention group would show (a) a shift in blame, acknowledging the difficulties that drivers face, (b) an improvement in post-intervention DBQ measures compared to the control group (primarily *motorcycle awareness*), and (c) a greater likelihood of clicking on the location from where a motorcycle could appear in our *hazard location test.*

4.2 Method

We recruited 148 car drivers who were allocated to either an intervention group (N = 71, 54 female, mean age 39) or a control group (N = 77, 52 female, mean age 40). The design of the study was almost identical to that of Study 2, with a few exceptions. The *risk test* was replaced by the DBQ scales (plus *motorcycle awareness* scale) used in Study 1, though the post-intervention questions were edited to reference future anticipated *errors*, *violations*, and *motorcycle awareness*. We also added *a hazard location task* to the battery. This latter task used clip M4 from Study 1 (Section 2.2, Figure 3). The hazard clip showed the ego car intending to turn into a side road, in-between stationary vehicles in the congested oncoming lane. The clip froze just before the hazard appeared (an oncoming motorcycle overtakes the standing traffic just as our car begins to turn) and participants were asked to click on up to three locations in the scene with their mouse where they thought a hazard could appear from.

The rest of the experiment followed Study 2 (see Figure 7), with the baseline test battery conducted online a week prior to the intervention and post-intervention battery. Participants either received the car-based intervention video or the hands-free mobile phone video. At the end of the study, we also asked them a series of direct questions regarding their thoughts on the video (e.g., “Did the video increase your understanding of why car drivers might crash with motorcycles?”). A more detailed methodology for Study 3 can be found in Appendix C.

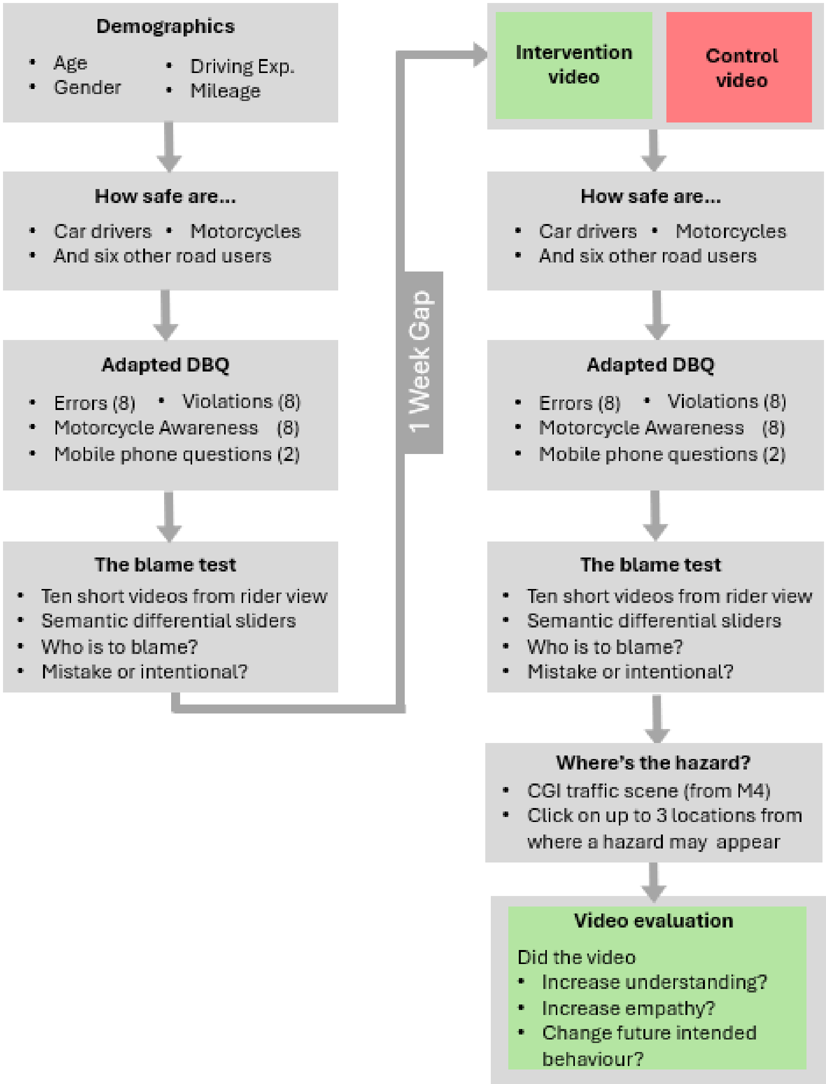


Figure 7. The blocks of the car driver study before (left) and after (right) the intervention.

4.3 Results

Analysis of the motorcyclist and car driver *perceived safety* ratings found our drivers to rate other car drivers safer than motorcyclists, $F(1,146) = 74.09$, $p < .001$). This opposite effect to Study 2 again reflects in-group bias (car drivers favouring other car drivers)., bias. Our participants also rated car drivers (but not motorcyclists) as less safe in the post-intervention battery, regardless of which video they had seen, $F(1,146) = 20.17$, $p < .001$.

The *blame test* found that our drivers mostly blamed the car drivers for the filmed incidents, but mostly attributed them to an error rather than a wilful violation. These scores did not change as a result of the intervention group being exposed to our video.

Regarding our DBQ scales, both groups reported an increase in future anticipated *errors*, a decrease in future anticipated *violations*, and most importantly, an increase in *motorcycle awareness* after the intervention. The increase in anticipated errors was greatest for the intervention group, suggesting they have become more concerned about making errors on the road.

The *hazard location test* demonstrated a clear influence of the intervention video. When asked to click on areas of the scene where a hazard might appear, the percentage of drivers who clicked on the location from where only a motorcycle hazard could appear was significantly greater within the intervention group compared to the control group (49% vs 24%, $Z = 3.15$, $p < .01$).

Finally, when our drivers were asked directly whether the intervention video had any positive benefits in terms of their *understanding* of why cars crash into motorcycles, *empathy* for the difficulties that motorcyclists face, and future intended behaviours in similar situations, the majority of riders reported improvements (with 92%, 88% and 88% recording varying levels of agreement with improvement in our three measures, respectively; see Figure 8). If we compare these self-reported improvements to those reported by our motorcyclists in Study 2 (Figure 6), we can see that similar portions of both road user groups agree with the improvements in understanding and changes to future behaviour. However, our drivers were more likely to agree that empathy had improved for the other group ($U = 3576.50$, $p < .01$). A more detailed results section for Study 3 can be found in Appendix C.

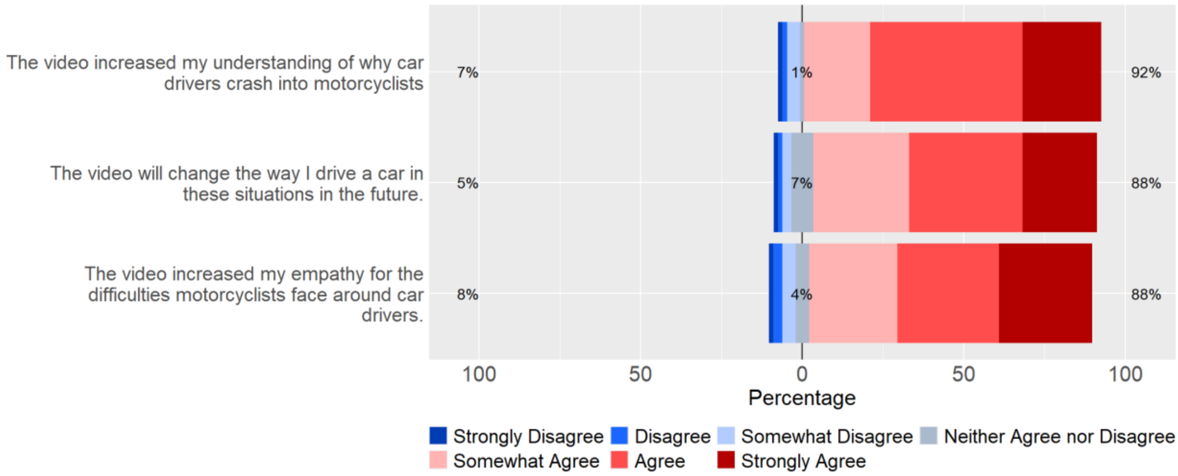


Figure 8. Drivers' agreement with belief statements regarding the video. Numbers reflect the percentage of the sample who disagreed, were ambivalent, or agreed with the statements (from left to right).

4.4 Discussion

Overall, the impact of the intervention video on our car drivers appears to be greater than the impact that was noted on our motorcyclists. When asked explicitly, our drivers were mostly in agreement that the intervention improved their understanding of the causes of car-motorcycle collisions (92%), increased their empathy for the difficulties that motorcyclists face (88%), and that the video will change the way they drive in similar situations in the future (88%).

In comparisons with the control group, the intervention also caused drivers to give higher estimates of their likelihood of committing driving errors in the future. It is possible that, due to the intervention content, our drivers now realise the greater possibility of making errors due to natural psychological biases in mental models, drivers' expectations, and the physiological limits of the visual system. If they previously believed they were good drivers (and most drivers do; Elvik, 2013) then merely telling them that 'drivers make mistakes' would be unlikely to influence their own self-perceptions (after all, it is *the other drivers* who make mistakes…!). The current safety messages however are based on universal psychological biases, backed up with visible evidence, which the average driver will find difficult to deny. They are not the seemingly subjective persuasive arguments which we can deem irrelevant based on illusionary superiority (e.g., "But *I* can handle speed", "*I* can drive safely while on the phone", etc.). Instead, they are facts that apply to *all* drivers, regardless of their own self-worth. For this reason, we argue that an increase in prospective DBQ errors (essentially, a decrease in confidence) is a positive sign that drivers will indeed heed the lessons in the intervention video.

Fortunately, this decrease in confidence following the intervention video is matched by an *improvement* in hazard prediction skill. Our post-intervention drivers were more likely to click on a hazard clip to identify a dangerous location from where only a motorcycle hazard could appear. This very concrete sign of improvement suggests that our intervention group has adapted their mental models for similar situations and now includes the possibility of motorcycle hazards. Together these two results are complementary: our drivers have improved their skill, but have decreased in confidence, avoiding the potential for increased over-confidence to wipe out any real-world benefit of training (e.g., Katila et al., 2004). There are parallels with studies investigating the Dunning-Kruger Effect (DKE), which suggests that low performers in a particular task (e.g., novices) can have the most inflated view of their skill level. This effect tends to decrease in those with greater actual skill levels (Kruger and Dunning, 1999; Navarro, et al., 2025), though we note there is a growing argument that the DKE is a statistical artifact rather than a window on metacognition (e.g., McIntosh, et al., 2022).

One possible confound lies with the gender split of our sample. While motorcyclists are predominantly male (reflected in the gender split in Study 2), the population of car drivers tend to be more evenly split between males and females. Accordingly, we did not seek to control gender in study 3, which resulted in a majority of female participants. It is possible that females would respond more positively to items regarding increased empathy and intentions to behave more safely in the future. To assess this, we compared males and females across all our reported dependent variables. Only the pre-intervention motorcycle awareness score was found to differ (p =.04, uncorrected), with males having slightly higher scores. If we correct our alpha level to compensate for familywise error (for 20 male vs. female t-tests) then this is no longer significant. Given these results, we conclude that the predominantly female sample has not influenced the pattern of results.

Some beneficial effects were noted for all participants, regardless of whether they were in the intervention group or the control group. All our drivers agreed they would commit fewer violations, expected to make more errors, and thought their motorcycle awareness would increase. Furthermore, while our drivers showed an in-group bias in their perceptions of other road users' safety (rating car drivers as safer than motorcyclists), they all showed a reduction in this bias in the post-intervention data collection phase. The most conservative way to interpret these effects is that there are systematic confounds in the data where the improvements are caused by something other than the manipulation, including the possible influence of simply measuring participant responses multiple times (e.g., the Hawthorn Effect; Diaper, 1990). It is possible that these blanket benefits across both groups derive from the assessment blocks that we provided, specifically the blame test. Though this was intended as a simple assessment of whether the intervention video would shift the blame criterion in participants, it is also possible that the blame test played a more active role in promoting safety-related changes in our drivers. Shahar et al. (2011) presented car drivers with hazard perception clips taken from the perspective of a motorcyclist. Afterwards, their car drivers reported more empathy, fewer negative attitudes, and a positive increase in safer attitudes towards motorcyclists. It is possible that our blame test created a similar effect in our driver groups, which might explain the overall changes in errors, violations, motorcycle awareness, and the significant shift in blame regardless of whether they were exposed to the intervention video. This provides an additional avenue of future research, exploring the role of motorcycle perspective hazard clips in supporting car drivers to re-evaluate their relationship with these vulnerable road users.

5. General Discussion

The aim of this project was to identify the impact of car drivers' mental models on their ability to spot motorcycle hazards, and then to use this evidence to form the basis of an intervention video designed to improve the attitudes and intended behaviours of car drivers and motorcyclists towards each other.

5.1 An Overview of results

The first study found one out of four scenarios to show the predicted effects, with car drivers having slower responses to a motorcycle hazard overtaking a line of stationary traffic as the ego car attempts to turn right from a side road onto the main carriageway. These car drivers also had significantly less *motorcycle awareness* (a score calculated as the sum of responses to six questionnaire items). Motorcycle awareness was found to predict how quickly drivers first looked at the motorcycle hazard, which in turn predicted how long they looked at, and presumably processed, the approaching motorcycle. Longer dwell times then predicted participants' hazard score for this clip. This predictive chain of behaviour supports the argument that experience with motorcycles leads to a greater chance of spotting motorcycle hazards (e.g., Magazzù et al, 2006; Crundall et al., 2012).

We then created two separate videos targeting motorcyclists and car drivers, built around the eye tracking videos extracted from Study 1. These videos were scaffolded with further information and activities intended to increase our road users' understanding of the causes of car-motorcycle collisions, increase their empathy for each other, and change their future intended behaviours on the road.

Study 2 compared a group of motorcyclists who were exposed to the intervention video, and a similar group who were exposed to a control video that had nothing to do with VRUs. Our intervention group mostly agreed that the video had improved their understanding (91%), future intended behaviours (85%), and empathy towards car drivers (65%). A selection of additional pre- and post-intervention measures were also collected, but none of these showed any improvements.

Study 3 followed a similar design, splitting a car driver sample into an intervention group and a control group. Again, most intervention drivers agreed that the video had improved understanding (92%), intended behaviours (88%) and empathy (88%). In a comparison between studies 2 and 3, we noted that our car drivers showed significantly greater agreement that their empathy had increased compared to our motorcyclists in Study 2.

Furthermore, our intervention group of car drivers also showed an increase in their expectation that they would commit errors in the future, presumably as a result of the intervention content that pointed out several natural psychological biases that all drivers can fall foul of. This decrease in confidence was however offset by an improvement in our intervention group's ability to pinpoint a hazard location in a CGI clip where a motorcycle hazard might emerge from (compared to a control group). This benefit occurred even though there was a distracting car-based hazard in the scene that could have dominated their attention. Note also that the task did not prompt our drivers to consider a motorcycle as the potential hazard, no motorcycle was visible in the clip, and the situation was a different perspective on a potential car-motorcycle collision that had not been considered in the intervention video. This arguably suggests far-transfer of training, whereby learning given in one context is extrapolated to different contexts.

Overall, the results show that motorcycle experience and awareness can influence one's chance of spotting an approaching motorcycle, and that this evidence can influence road users' attitudes, intended future behaviours, and even hazard prediction skill. The training benefits were limited to explicit introspection in our motorcycle group, but the findings were more convincing in our car driver group.

5.2 Why is the intervention more successful with drivers than motorcyclists?

Why did our intervention have a stronger effect with drivers than motorcyclists? First, one should note that our intervention video focused on the causes of car-motorcycle collisions, which are often the fault of the car driver (e.g., Clarke et al., 2007). For this reason, we may speculate that our motorcyclists may have felt less reason to reassess their level of empathy for car drivers.

There is however a more psychologically interesting reason that may explain the weak effects noted with our motorcyclists: "Groups in a numerical minority express more bias than those in a numerical majority" (Hewston et al., 2002, p585). As motorcyclists are very much the minority group in this interaction, their group bonds are likely to be stronger, and thus in-group bias is more likely to persist. With this in mind, it is understandable that an intervention that was perhaps 95% identical would have more impact on the larger group.

5.3 Limitations

In any study of real-world behaviours, researchers must make compromises. In Study 1, we forwent the sanctity of the laboratory in favour of testing participants in the field (or rather, at a national motorcycle event). This approach was deemed necessary in order to recruit sufficient motorcyclists to take part in the VR study, as previous experience suggests it can be impossible to get large numbers of such a niche population into the lab. We aimed to minimise the impact on results by testing all of our control participants in similar public locations. While this should have removed any gross systematic biases, the clamour and bustle of these unorthodox testing environments undoubtedly added noise to the data.

In Study 2, we found that our motorcyclists did not improve on any of our pre/post measures following the intervention (and only reported benefits when explicitly asked). While we have discussed possible psychological explanations, we also acknowledge that the blame test and the risk test may not have captured the best scenarios to measure training benefit. For instance, the risk test produced remarkably sedate speed scores, with average reported speeds of 26 mph in the pre-intervention group (despite one of the two bends being in a 50-mph zone). This suggests there may have been a floor effect in the risk items that was not picked up in initial piloting.

We also noted that the blame test only hinted at an effect in our car driver group and showed no changes with our motorcyclists. It is possible however that the clips themselves were contributing to some of the pre/post changes we noted in our car drivers regardless of whether or not they saw the intervention video. Our blame clips were the only stimuli that our car-driver control group saw which contained motorcycles, so there is a high likelihood that they may be responsible for the improvements in motorcycle awareness noted in our control group (and possibly the improvement in violations also). One explanation is that the clips have a beneficial effect in the same way that Shahar et al., (2011) changed drivers' attitudes to motorcyclists by providing them with clips from the rider's perspective. While this possibility may have confounded the measures we recorded from these clips, it has provided an alternative avenue for developing training resources that may complement our current intervention videos.

Finally, it is worth considering whether the beneficial effects of watching the intervention videos are likely to persist or wane over time. One recent study (Crundall and van Loon, 2023) found empathy-evoking videos to improve car drivers' attitudes and future intended behaviours towards horse riders and cyclists, though when they followed-up their sample 16 months later, all benefits had disappeared (Crundall and van Loon, 2024). We do not have current data as to whether the current benefits would similarly decay, but researchers have previously noted that one-shot, experimentally induced attitude change can revert within two weeks (Cook and Flay, 1978). We recommend that all attitude change research that shows immediate benefit should be followed-up (preferably within six months), and that more systematic research be undertaken on the conditions required for achieving persistent attitude change within the driving safety field.

5.4 What next?

The next steps after creating and validating a video training resource often focus on dissemination. The intervention video has been shown to have beneficial impacts on our car drivers, and we still received positive feedback from our motorcycle participants when asked explicitly. On this basis we are comfortable disseminating this as a resource targeting car drivers, but questions remain about the efficacy of targeting motorcyclists. We believe this video *will* increase understanding in motorcyclists, but the value received may not be as great as that offered by alternative motorcyclist training resources (e.g., motorcycle-specific hazard perception training).

For car drivers, this video could act as a support resource for drivers engaged in diversionary courses or could provide companies with a resource to include as a part of professional driver training.

Alternatively, the length of the video may fit a 'toolbox talk' slot (short, frequent talks on professional issues that are often given in a staff briefing at the start of the day).

Prior to release there are still some iterations that we would like to include. For instance, for testing purposes we used a member of the research team to provide the voice over. We would prefer to bring in a voiceover artist to provide a more professional audio track. This would not just improve the quality of the video but would also increase the face validity of the information that we are imparting – a key consideration in the implementation of behavioural change techniques.

Beyond dissemination however, this research has raised new possibilities for designing and combining multiple techniques, including the possibility of emulating Shahar et al.'s (2011) perspective taking approach with car drivers, or by designing hazard perception tests to include more motorcycle hazards that evoke similar responses to clip M1. For instance, filtering in traffic is a legal and attractive method of progressing on a motorcycle, but this practice carries with it a greater risk of collision (Clabaux et al., 2017). Hazard clips that include filtering motorcycles may therefore also differentiate between dual drivers and car drivers, much as M1 did, while motorcycle-perspective clips of filtering could help drivers further develop empathy for the rider's plight. Furthermore, this approach can be extended from targeting car drivers, to bigger vehicles that have different challenges when interacting with motorcycles (such as HGVs and their associated blind spots). We encourage other researchers to explore these issues in our continued efforts to reduce car-motorcycle collisions.

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Appendix A: Study 1

A1 Introduction

The aim of this study was to confirm whether experience of motorcycle riding made drivers safer around other motorcyclists, as indicated by eye movements (e.g., do they spot a motorcycle hazard faster than other drivers) and speed of response to the hazard (reflected in the points they score, as per the DVSA hazard test). We recruited ordinary car drivers and dual drivers (car drivers who also ride motorcycles) and placed them in eight 360-degree CGI scenarios. Four of the scenarios contained a motorcycle hazard. We predicted that our dual drivers would out-perform ordinary car drivers on one or more of these clips.

A2 Method

A2.1 Participants

A total of 121 car drivers and dual drivers took part in the study. The majority of motorcycle participants were recruited and tested at the MCN London Motorcycle Show 2024. All other participants were tested in a variety of public venues to ensure comparability of the testing environment. Seventeen participants were excluded due to technical issues with the eye tracking or response data (14), cybersickness (1) or not having followed the instructions (3). Of the 104 remaining participants that completed the study, 49 were car drivers and 55 dual drivers. The average age of the car drivers was 44.2 years, while our dual drivers averaged 49.8 years (see Table A1).

A2.2 Design and Procedure

This study used a 2 x 2 mixed design, with participant group (dual drivers vs. car drivers) as the between-subjects variable, and hazard type (four motorcycle hazards vs. four pedestrian/car hazards) as the within-subjects variable. The primary dependent variables of interest were participants' hazard perception (HP) performance, and two measures of eye movement behaviour: time to first fixate (look at) the hazard source, and total dwell time (gaze) on the hazard source. HP performance was calculated as a score following the same system used for the official DVSA HP test.

Table A1. Demographics of the car and dual drivers.

	Car Drivers	Dual Drivers	Comparison
Number of participants	49	55	
Number of females	12	11	$\chi^2 = 0.64$, $p = .38$
Age	44.2	49.8	$t = -1.93$, $p = .06$
Experience since passing test (years)	23.7	28.4	$t = -1.69$, $p = .09$
Annual Mileage (car)	7662	14770	$t = -2.47$, $p < .05$
Annual Mileage (motorcycle)		5161	

A temporal scoring window was placed around each hazard and was sub-divided into five equally sized windows. A response in the first sub-window scored five points, a response in the second sub-window scored four points, and so on. Responses outside the scoring window scored zero points. Eye movement measures were calculated by setting Areas of Interest (AOIs) around each hazard using Tobii Pro Lab Eye-tracking software, and the time taken from hazard onset to the eye first landing in an AOI was taken to reflect how quickly a participant looked at the hazard, while the total dwell time in the AOIs represented processing time.

Before taking part in the hazard perception test, participants completed a demographics questionnaire to gauge their age and gender, and their driving and riding history. Following the initial demographic questions, participants were given instructions on how to complete a hazard perception test (following Crundall, van Loon, et al., 2021). The instructions prompted participants to respond to hazards that were developing into situations where they might need to brake, decelerate or steer to avoid a collision. The hazard perception test consisted of eight 360-degree CGI clips presented in a Virtual Reality headset. After calibration of the participant's eye movements, a practice clip was provided to familiarise participants with the task as well as the virtual environment. At the end of the practice clip, participants were asked to rate their symptoms of cybersickness before continuing with the study. One participant was removed at this point.

After completion of the hazard perception test, participants were asked to complete an adapted version of the Manchester Driver Behaviour Questionnaire (DBQ) with the 8 Error items and the 8 Violation items of the original DBQ (Lajunen, et al., 2004) plus an additional 6 items related to the perception of, and behaviour towards, motorcyclists which can be found in Table A2 (adapted from Crundall, Clarke, et al., 2008). This questionnaire was given after completing the hazard perception task to avoid participants anticipating that the study would be focused on motorcycles.

A2.3 Stimuli and Apparatus

The hazard test was presented in an HTC Vive Virtual Reality headset with a resolution of 2160 × 1200 pixels (1080 per eye) and a 110-degree Field of View (FOV), running Tobii Pro Lab. Responses were made by pressing the space bar on a keyboard. A description of the eight CGI hazard clips (four with motorcycle hazards and four with 'other' hazards) can be found in Table A3 (see also Figure A1 for screen shots of the four motorcycle clips at the point where the hazards first became visible).

Table A2. Six motorcycle-focused items that were included with the 8 error and 8 violation items of the Driver Behaviour Questionnaire, each preceded by "When driving a CAR, how often do you do the following?" Answers were given on a 6-point scale ranging from 'never 0' to 'nearly all the time 5').

Statement
1. Find yourself surprised by a motorcyclist filtering between lanes^R.
2. Check specifically for approaching motorcycles when pulling out of a side road.
3. Consider that motorcyclists might be hidden from your view by other traffic.
4. Have difficulty spotting a motorcyclist in your mirror^R.
5. Consider the possibility that a motorcyclist may be trying to overtake you before you make an overtaking manoeuvre.
6. Find it easy to assess the speed of an approaching motorcycle.

Note: ^{R} refers to scores that are reversed for analysis.

Table A3. A description of the four motorcycle and four 'other' hazard perception clips with their duration and hazard onset.

Clip	Hazard description	Duration	Onset
Motorcycle clips			
M1	You approach a T-junction intending to turn right. There is a standing line of traffic from the right, and infrequent traffic from the left. A motorcycle from the right overtakes the standing traffic (30mph) as you make the turn.	0:32	0:16
M2	You are driving along a suburban road approaching congestion. Your sat-nav reports that there is a faster route if you take the side road immediately to your right. A motorcycle overtakes you from behind as you turn.	0:40	0:24
M3	You approach a crossroads intending to turn right. At the junction, an oncoming HGV waits to turn right also, potentially obscuring oncoming traffic. As you make the turn, an oncoming motorcycle emerges from behind the lorry.	0:33	0:13
M4	There is a standing line of traffic in the oncoming lane. You intend to turn into a side road on the right. A car approaches slowly from this side road but does not pose a threat. Instead, an oncoming motorcycle decides to overtake the standing traffic just as you try to make the turn.	0:50	0:44
Other clips (non-motorcycle hazards)			
O1	While travelling in the right lane of a two-lane carriageway, the car immediately ahead, indicates and moves over into the left lane. Unfortunately, he fails to see a car in the left lane, hidden in his blind spot. The manoeuvring car narrowly misses the car in the left lane, but the latter driver pulls out immediately into the right lane to overtake. The overtaking manoeuvre of this second car is the hazard.	1:17	0:53
O2	You are driving along a narrow street with parked cars on either side. An oncoming car flashes its lights, as if to allow you through the bottleneck of parked vehicles. A second driver, visibly approaching from a side-road, misinterprets this signal to suggest he can pull out. As you drive forward, the car suddenly emerges from the side road.	0:46	0:36
O3	When trying to overtake a stationary bus, a car can be briefly seen approaching from a side road on the left, ahead of the bus. As you pass the bus, the car pulls out of the side road.	0:50	0:31
O4	A zebra crossing precedes a mini roundabout ahead. A pedestrian from the left crosses in good, time, but a pedestrian on the right crosses in front of you. His intention to cross is signalled by a change in trajectory and a glance at your car, but an oncoming vehicle then obscures him. After this vehicle passes, the pedestrian appears on the crossing in front of you.	0:54	0:13

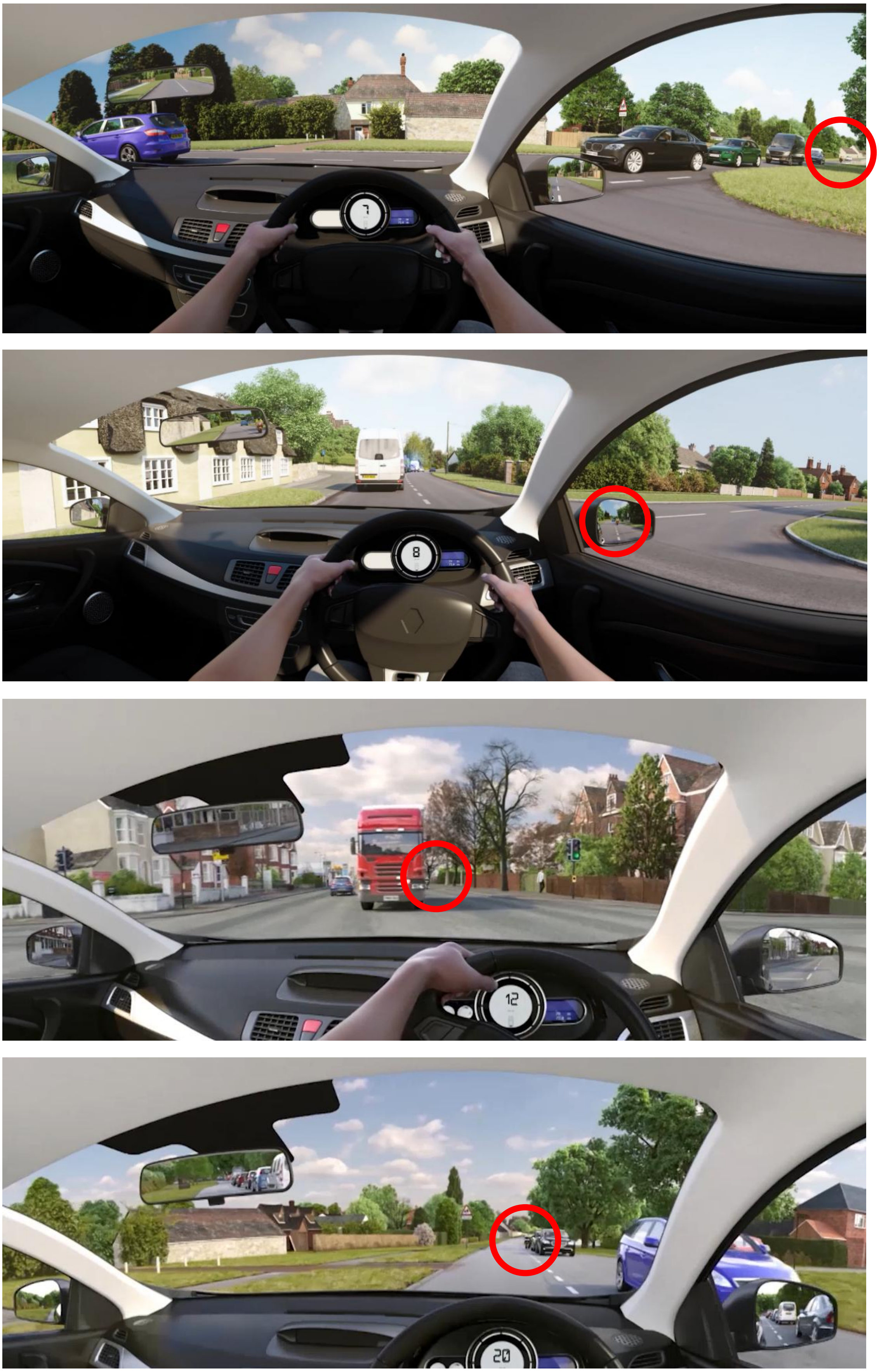

Figure A1. Screenshots of the four motorcycle hazards as they begin to develop (M1 to M4, from top to bottom). Red circles have been added to show where each motorcycle hazard is first visible.

A3 Results

A3.1 Errors, Violations and Motorcyclist awareness

Questionnaire items were combined as factors and gave moderate to acceptable Cronbach's alphas. There was no difference in self-reported errors and violations across our two groups of drivers, but dual drivers reported greater motorcyclist awareness (Table A4).

A3.2 Comparison of hazard perception scores between car drivers and dual drivers

Combined hazard perception scores for the four motorcycle clips and the four other clips were compared across driver group in a 2 x 2 Analysis of Variance. There was a main effect of clip type, $F(1,102) = 67.75$, $p < .001$, with scores for the motorcycle clips being lower than for the non-motorcycle clips (10.0 vs 13.5 for the dual drivers and 9.10 vs 13.5 for the car drivers, respectively; out of a maximum of 20 points). No significant differences were found between our dual drivers and our car drivers. However, as noted in the introduction, we expected some of the clips to be more effective at showing a dual driver benefit than others and had therefore planned to compare the two groups across each individual clip. Looking at the individual motorcycle clips, we found a difference in hazard perception performance for the first Motorcycle clip (M1), with the dual drivers outperforming the car drivers (see Table A5).

Table A4. Factor scores of the car and dual drivers.

	Cronbach's alpha	Car Drivers	Dual Drivers	Comparison
Errors (DBQ)	0.79	0.90	0.80	$t = .87$, $p = .39$
Violations (DBQ)	0.78	1.42	1.27	$t = 0.97$, $p = .34$
Motorcyclist awareness	0.66	2.92	3.75	$t = -6.20$, $p < .001$

Table A5. Mean hazard perception scores for car drivers and dual drivers (out of 5)

	Car Drivers	Dual Drivers	Comparison
M1	1.67	2.40	$t = -2.27$, $p < .05$
M2	1.45	1.64	$t = -.46$, $p = .64$
M3	2.61	2.58	$t = .11$, $p = .92$
M4	3.37	3.42	$t = -.17$, $p = .87$

A3.3 Comparison of eye movements between car drivers and dual drivers

A similar pattern was found when looking at eye movement behaviour, with clip M1 showing differences between the two groups whereas the other clips did not. On average, our dual drivers fixated the motorcycle hazard in M1 more than a second earlier than the car drivers and spent nearly half a second longer looking at it (see Tables A6 and A7, respectively).

Table A6. Mean time to first fixate (ms) the motorcycle hazard for the car and dual drivers, calculated from the time the motorcycle hazard was first visible.

	Car Drivers	Dual Drivers	Comparison
M1	4672	3563	$t = 2.72$, $p < .01$
M2	6064	5691	$t = .54$, $p = .59$
M3	577	757	$t = -1.29$, $p = .20$
M4	1081	1151	$t = -.61$, $p = .54$

Table A7. Mean dwell time (ms) on the motorcycle hazard for the car and dual drivers.

	Car Drivers	Dual Drivers	Comparison
M1	795	1227	$t = -2.29$, $p < .05$
M2	547	894	$t = -1.25$, $p = .21$
M3	1203	1199	$t = .02$, $p = .98$
M4	1788	1755	$t = -.29$, $p = .78$

A3.4 Predicting hazard scores and eye movement behaviour

The above analyses showed that dual drivers were faster to spot the motorcyclist in clip M1, spent more time looking at it, and scored more points on the hazard perception task. A linear regression was then carried out to see whether hazard perception scores on the motorcycle clips were predicted by the two eye movement parameters (see Appendix A for regression tables). Demographics (age, gender, car driving experience and annual mileage), and the DBQ factors (errors, violations, motorcycle awareness) were also included. The model was significant, $F(9,89) = 5.39$, $p < .001$ and explained 38% of the variance. The only significant predictor was the dwell time on the motorcycle hazard, where longer gaze on the hazard predicted a higher hazard perception score.

When this analysis was repeated across the three other motorcycle hazard clips, all clips showed an improvement in hazard score with greater dwell times. Clip M3 (the motorcycle appears from behind an HGV) was also influenced by participants' time to first fixate the hazard, with quicker fixations relating to faster hazard responses, as one might expect. See Table A8 for details.

We then carried out two further linear regressions with the eye movement parameters (time-to-first-fixate and dwell time) as criterion variables and the demographics and DBQ factors as predictors. Dwell time was significantly predicted by the time taken to first fixate the motorcycle hazard for all four motorcycle clips (Table A9), with earlier fixations leading to longer glances. There was also a small effect of age on dwell time for M4, with older participants having shorter dwell times.

The time taken to first fixate the motorcycle hazard was significantly predicted by motorcycle awareness for M1, but this did not hold for the other three clips (Table A10). For M3, there was a dissociation between age and experience: increased age slowed the speed with which the motorcycle hazard was fixated, whereas more years of driving experience led to faster fixation of the motorcycle hazard.

Table A8. T-values for significant predictors of hazard perception performance for the four motorcycle clips and F values and R^2 values for each model.

	M1	M2	M3	M4
Age	-.05	1.21	.86	.73
Gender	.70	-1.05	.13	-.02
Annual mileage	1.07	-.20	-.31	-.40
Experience	-.29	-1.30	-.49	-.59
Errors	.14	-.21	-1.37	-.85
Violations	.55	-.12	.39	1.47
Motorcycle awareness	.32	-.69	-.72	.43
Time to first fixate	-1.27	1.90	-2.26*	-.94
Dwell time	3.11**	2.89**	3.73***	3.13**
Df	9,89	9,59	9,92	9,96
F	5.39***	1.39	10.53***	8.31***
R^2	0.38	0.20	0.53	0.46
$R^2_{adjusted}$	0.31	0.06	0.48	0.41

Note: *<.05, **<.01, ***<.001

Table A9. T-values for significant predictors of dwell time for the four motorcycle clips, and F values and R^2 values for each model.

	M1	M2	M3	M4
Age	.81	.64	-.41	-2.16*
Gender	-.71	-.52	-.72	-1.67
Annual mileage	1.42	1.55	1.35	-.04
Experience	-.74	-.81	.97	1.48
Errors	-.89	-.17	.39	-1.49
Violations	-1.57	.54	-.87	.03
Motorcycle awareness	.01	1.44	-.86	.27
Time to first fixate	-8.25***	-9.21***	-12.79***	-17.43***
Df	8,95	8,63	8,98	8,104
F	13.70**	17.45***	25.33***	45.44***
R^2	0.56	0.72	0.69	0.79
$R^2_{adjusted}$	0.52	0.68	0.67	0.77

Note: *<.05, **<.01, ***<.001

Table A10. T-values for significant predictors of time to first fixate for the four motorcycle clips, and F values and R^2 values for each model.

	M1	M2	M3	M4
Age	.68	-.02	3.20**	.39
Gender	.36	1.13	-.71	1.46
Annual mileage	-.99	-.98	-1.03	-.65
Experience	.03	.71	-3.15**	-.52
Errors	-.87	.99	.45	-.04
Violations	-.36	-1.84	-.10	.13
Motorcycle awareness	-4.46***	-1.14	.61	.21
Df	7,95	7,63	7,98	7,104
F	4.51***	2.27*	1.81	0.78
R^2	0.26	0.22	0.12	0.05
$R^2_{adjusted}$	0.21	0.12	0.06	-0.02

Note: *<.05, **<.01, ***<.001

Appendix B: Study 2

B1 Introduction

The aim of this study was to create a video that details the psychological mechanisms which might explain why car drivers crash with motorcycles, building on eye tracking videos extracted from the VR headset in Study 1. This was intended to reduce motorcyclists' out-group bias towards car drivers that might otherwise affect their perceptions of, and behaviour around, these other road users. Compared to a control group, we predicted that motorcyclists who were exposed to our intervention video would show increased regard for car drivers (e.g., think that they are generally more safe on the roads), be more willing to share the blame for incidents with ambiguous antecedents, and would change their intended behaviour in risky scenarios similar to those included in the intervention video.

B2 Method

B2.1 Participants

Motorcyclists were recruited from an online paid participant panel (www.Prolific.com) and were recompensed with £5.25 for an average time commitment of 35 minutes (reflecting an hourly rate of £9). A total of 166 participants completed the motorcyclist intervention study (121 male and 45 female). There were 78 in the intervention group and 88 in the control group (with a slight imbalance due to more of the intervention participants failing to complete the study). The average age of our participants was 42.7 ranging from 19 to 77 years. They rode an average of 3282 miles per year (*SD* = 8667) on their bike. Ninety-five percent of the sample also drove a car and reported 7816 miles per year (*SD* = 6673). Demographics are broken down across the group in Table B1.

Table B1. A breakdown of demographic measures across the intervention and control group. Comparisons show that minor differences in the group do not reach statistical significance.

	Intervention	Control	Comparison
Number of participants	78	88	
Number of females	23	21	χ^2 = 0.67, p = .41
Age	42.7	42.7	t = -0.01, p = .99
Annual Mileage (car)	8302	7388	t = 0.86, p = .39
Annual Mileage (motorcycle)	3796	2822	t = 1.65, p = .10

B2.2 Design and Procedure

The online study was prepared using Qualtrics survey software (www.qualtrics.com). The intervention study consisted of two surveys that were presented one week apart. The first survey (which took around 10 minutes to complete) consisted of demographic questions (gauging the participants' age, gender, and driving history) and three blocks of assessments (see Section 3.2, Figure 4).

To gauge attitudes towards car drivers and motorcyclists without drawing attention to these road users, the first question asked participants how safe they considered typical users of certain vehicles to behave on the road: car drivers, motorcyclists, HGV drivers, cyclists, bus drivers, van drivers, taxi drivers and tractor drivers on a scale from 1 (*very unsafe*) to 6 (*very safe*).

In the next block, participants were shown ten short videos (between 6 and 31 seconds) of traffic situations, filmed from a motorcyclist's perspective in urban and suburban areas and on motorways (the *blame test*). These videos were taken from online collections of motorcycle videos, and each one showed a near collision between the motorcyclist and a car driver (see Table B2). For example, in one clip a motorcyclist almost collides with a car immediately ahead when it brakes sharply.

Table B2. A description of the ten clips contained in the Blame Test

Name	Description	Duration (seconds)
Clip 1	A motorcyclist nearly collides with the back of a car when the car suddenly brakes sharply.	11s
Clip 2	A motorcyclist is traveling at speed down a country lane when a car starts to pull out from a concealed driveway on the left, partially hidden by hedges. This prompts the motorcyclist to move into the oncoming lane.	17s
Clip 3	Traffic is moving along a dedicated merging lane onto a motorway. When the traffic lights for an adjacent, access-controlled roundabout change to red, the car ahead suddenly brakes, mistakenly assuming the light applies to their lane. This causes the motorcyclist behind to brake sharply, coming close to a rear-end collision.	17s
Clip 4	A motorcyclist is traveling down a suburban road, briefly looking at their phone in a mounted holder. When they look up, they notice a parked car has started to pull out, bringing them close to a potential collision.	13s
Clip 5	A car is positioned in the middle of the lane approaching a roundabout to go straight across. The motorcyclist positions themselves slightly to the left within the same lane, also intending to go straight. As they proceed onto the roundabout, the car begins moving left, seemingly unaware of the motorcyclist, which brings them close to a potential collision.	21s
Clip 6	While traveling down a motorway, a van remains in lane 2, so the motorcyclist moves into lane 1 to undertake. After this, the van accelerates and moves into lane 1 cutting in front of the motorcyclist.	31s
Clip 7	While traveling in the middle lane of a three-lane road, where the two left lanes merge into one after the traffic lights, a car undertakes a motorcyclist.	14s
Clip 8	A motorcyclist is traveling down a suburban road when a car suddenly pulls out from a side road on the left, coming close to causing a collision.	6s
Clip 9	Whilst turning right on a roundabout, a car suddenly cuts across your path into the next lane. Then, cuts across again into your lane forcing you to stop.	16s
Clip 10	Whilst the motorcyclist is overtaking the parked car on the left, the car suddenly pulls out to use the side road on the right to make a U turn.	18s

After the videos (which participants were able to replay multiple times if required) participants were asked to indicate what they thought was the balance of responsibility split between the motorcyclist and the other road user for the near collision (taken from Crundall,et al., 2013). Participants could make their response by moving a slider on a scale from 'motorcyclist completely to blame' to 'car driver completely to blame'. In a similar way, participants were asked to indicate with a slider how much they thought the near collision was due to an error of judgment or an intentionally risky act. The slider recorded scores from 0 to 100, with higher scores reflecting blame attributed to the car drivers and attribution of the event to a wilful violation.

Finally, participants were shown a further seven short videos, which they were able to replay as often as needed in order to make their judgements (the *risk test;* see Table B3). Two of the videos were of motorcyclists approaching a bend on a country road (with a 30mph and 50mph limit, though speed signs were not visible in the pictures). Participants were asked what speed they would choose when navigating that bend. A third video showed a motorcyclist approaching a junction and participants were asked what speed they would choose to go through that junction. Four further questions asked participants whether they would overtake in the scenario shown. These overtaking videos showed situations with or without a car about to pull out from a side road and with or without an oncoming car. Those participants who responded that they would overtake in a particular scenario were then asked at what speed they would overtake.

Table B3. A description of the seven clips contained in the Risk Test

Name	Description	Decision question	Speed question	Duration (seconds)
Clip 1	A motorcyclist travelling down a country road, approaching a bend where the speed limit changes to 30mph.	N/A	At what speed would you go through this bend?	5s
Clip 2	A motorcyclist travelling down a country road, approaching a bend with a speed limit of 50mph.	N/A	At what speed would you go through this bend?	4s
Clip 3	A motorcyclist overtaking vehicles down a congested urban road, approaching a junction where an oncoming car is intending to turn into a side road on the left.	Would you overtake here?	At what speed would you overtake?	2s
Clip 4	A motorcyclist is overtaking vehicles down a suburban road, approaching an empty side road on the left.	Would you overtake here?	At what speed would you overtake?	3s
Clip 5	A motorcyclist is traveling in the right-hand lane to go straight through the junction, with a clear view of both the junction and any approaching vehicles.	N/A	At what speed would you go through this junction?	4s
Clip 6	A motorcyclist is overtaking vehicles down a congested urban road, passing an empty side road on the left.	Would you overtake here?	At what speed would you overtake?	3s
Clip7	A motorcyclist is overtaking vehicles down a congested urban road, approaching a side road on the left with a car beginning to pull out.	Would you overtake here?	At what speed would you overtake?	2s

Participants received the link to the second part of the study one week after completion of the first part, at which point they were randomly allocated to either the intervention or control condition. Participants in the intervention condition were shown the intervention video, whereas participants in the control condition watched a video about the dangers of handsfree mobile phone use during driving. After watching the road safety video, participants were presented with the same blocks of assessment as in the first study (see Section 3.2, Figure 4).

For participants in the intervention group the second study was concluded by three Likert scale questions about the video that the participants had watched (asking how it had changed their understanding of car-motorcycle collisions, increased their empathy for the difficulties that car drivers face when interacting with motorcycles, and whether the video had changed their future intended riding behaviour in similar situations). A free text box was also provided to allow additional feedback.

B.2.3 Stimuli

The intervention video for motorcyclists was 14:43 minutes long. The script for the video was built around the eye-tracking recordings of a car driver and dual driver while watching clip M1 (taken from Study 1). Other elements were added to the script based around the three behaviours noted in Figure 1 (*look, recognise, appraise*). Specifically, the persuasive arguments were based on the following:

- Drivers don’t know where to look for riders because they don’t have enough experience of these road users. This is a natural psychological bias which occurs because there are so few motorcycles on the road compared to other vehicles.
- The small size and unexpected nature of motorcyclists make them harder to identify. Again, this does not reflect low skill or effort on the part of the car driver. It is another natural bias.
- Finally, we explain how difficult it is to estimate the speed of an approaching motorcycle, partly due to the narrow profile of riders and the limitations of the visual system (see Figure 5 for screen shots).

The control video was a road safety video about the dangers of handsfree mobile phone use whilst driving (8:57 minutes) used in a previous study (Crundall et al., 2024).

B3 Results

B3.1 Video evaluation

As can be seen in Figure 6 (Section 3.3), a large majority of motorcyclists (91%) reported that the intervention video had increased their understanding of why car drivers crash into motorcyclists, and that it will change the way they ride a motorcycle in the future (85%). Nearly two-thirds of the sample also reported increased empathy for the difficulties car drivers face around motorcyclists (65%).

In addition to these items, respondents had the opportunity to provide written feedback. The comments aligned with our aims of helping riders understand some of the causes behind car-motorcycle collisions. Examples include:

> "This was great to raise awareness. I thought car drivers were just ignorant, but this [has] slightly changed my perspective and also shown me to look out more myself. I wish a lot more people could see this."

> "I am already a very nervous biker so while it will likely make me more hazard-aware, for me the main change is that (as a non-car driver especially) I understand a little better how interacting with bike traffic is from the perspective of a different vehicle."

> "The video was interactive and thought provoking and gave you an understanding of the reasons why bikers are not seen in accidents."

B3.2 Perceived safety of motorcyclists and car drivers

Participants were asked to rate the safety of various road users (including an average motorcyclist and average car driver) on a six-point scale. A 2 x 2 x 2 mixed ANOVA compared the ratings for the average motorcyclist and car driver across intervention condition, and pre/post data collection phase. The results showed a small but significant main effect reflecting in-group bias, with our motorcyclists reporting greater safety for average motorcyclists than for average car drivers, $F(1,64) = 4.58$, $p < .05$. No significant differences were found due to the intervention condition (intervention vs. control group), or when the data was collected (before or after having seen the intervention or control video). Mean safety ratings are given in Table B4.

Table B4. Motorcyclists' views on how safe car drivers and motorcyclists are on the road in general (ranging from 1 very unsafe to 6 very safe) for both the intervention and control group, pre and post intervention.

	Intervention		Control	
	Pre	Post	Pre	Post
Perceived safety of motorcyclists	4.2	4.2	4.0	4.0
Perceived safety of car drivers	3.9	3.8	4.0	3.9

B3.3 The Blame Test

Participants were asked to attribute blame for ten near collisions on a scale of 0 (motorcyclist completely to blame) to 100 (car driver completely to blame). Average responses for the ten clips ranged from 53 to 92, i.e. from about an even split of blame between motorcyclist and car driver to the car driver almost entirely to blame. When combining the ten scenarios, a 2 x 2 ANOVA showed no significant differences in attributed blame between the intervention and control group, nor any change in blame dependent on when data were recorded (pre vs post). Participants were also asked what they thought the cause of the near collision was, ranging from completely the result of a mistake of judgment (0) to entirely an intentional act (100). Five clips were considered errors (with ratings from 24 to 28), one an intentional act (rating 82) and the remaining four fell somewhere in-between (with ratings from 48 to 65). These ratings did not change significantly after the intervention, and there were no differences between the two groups (see Table B5).

Table B5. Motorcyclists' attribution of blame and cause in near collisions (ranging from 0 'motorcyclist completely to blame' to 100 'car driver completely to blame' and 0 'error of judgment' to 100 'intentional risky act') for both the intervention and control group, pre and post intervention.

	Intervention		Control	
	Pre	Post	Pre	Post
Attributed blame	73.5	74.1	72.1	73.6
Attributed cause	42.2	41.5	45.6	44.9

B3.4 The Risk Test

To compare intended behaviour between the intervention and control group before and after the intervention, we calculated the percentage of scenarios (out of four) where participants said they would overtake and their average intended speeds when taking bends (two scenarios) and overtaking (five scenarios). A series of 2 x 2 (pre/post x intervention condition) ANOVAs showed no significant differences between the two groups, nor any difference due to the intervention for overtaking intentions or for intended speeds when taking bends or overtaking (see Table B6).

Table B6. The number of intended instances of overtaking (out of four scenarios) and average intended speeds when taking bends (two scenarios) and overtaking (five scenarios) for both the intervention and control group, pre and post intervention.

	Intervention		Control	
	Pre	Post	Pre	Post
Overtaking intention (out of 4)	1.84	1.76	1.88	1.68
Speed in bends (mph)	26.0	26.0	26.9	26.1
Speed when overtaking (mph)	20.4	20.7	20.7	20.9

Appendix C: Study 3

C1 Introduction

The rationale for Study 3 was identical to that of Study 2, yet with a focus of changing the attitudes and future behaviour of car drivers towards motorcyclists, rather than the other way around. To this end the intervention video was changed slightly, to make it more relevant to car drivers, and the motorcycle-specific risk test was dropped from the battery, in favour of our DBQ scales that were used in Study 1 and a hazard location task. We predicted that our car drivers would show improvements in one or more of these measures after being exposed to the intervention video, compared to the control group.

C2 Method

C2.1 Participants

One hundred and forty-eight car drivers completed the online intervention study (40 male, 106 female, 2 other/prefer not to say, with an average age of 39.4 ranging from 18 to 81 years). Of these 71 were assigned to the intervention group and 77 to the control group. The imbalance was due to slightly more intervention participants starting but failing to complete the study. Participants drove an average of 6676 miles (*SD* = 3664) a year. Demographics are broken down across the group in Table C1.

Table C1. A breakdown of demographic measures across the intervention and control group. Comparisons show that minor differences in the group do not reach statistical significance.

	Intervention	Control	Comparison
Number of participants	71	77	
Number of females	54	52	χ^2 = 0.83, p = .36
Age	38.6	40.1	t = -0.69, p = .49
Annual Mileage (car)	6639	6710	t = -0.12, p = .91

C2.2 Design and procedure

The design of the car driver intervention study was largely the same as that for the motorcycle intervention study, with a few exceptions. The risk test was removed and was replaced with the adapted Manchester Behaviour Questionnaire used in Study 1, with 8 Error items, 8 Violation items, and the 6 'Motorcyclist awareness' items used in Study 1. Two additional items asking about the frequency of making handsfree and handheld mobile phone calls were added to provide our control participants with items that were relevant to the video they saw.

Participants were also shown a short CGI clip (M4, Study 1). The clip ended just before the motorcycle hazard became visible and participants were asked to click on up to three locations on the final frame to reflect where they were most likely to look for a developing hazard (Figure C1). The clip ended just as the driver intended to turn right into a side road. Two *a priori* hazard locations were identified: a car waiting in the side road, and the area of the scene directly ahead where a motorcycle could appear from (and does appear from if the video had moved on to subsequent frames).

C2.3. Stimuli

The car driver intervention video was 14:06 minutes long. The majority of the content was the same as that for the motorcyclist study, but the video was edited to make it more relevant to drivers. It also contained specific recommendations tailored to car drivers:

- Always look for overtaking motorcycles in the presence of standing traffic
- Remember to look for motorcycles when changing your route due to congestion
- Look out for motorcycles when changing lanes in slow moving traffic
- Always be prepared to stop at a give-way line
- Give longer glances down the road when deciding whether to pull out from a side road
- Be aware that motorcycles are hard to see and can be hidden among the background
- Don’t make snap judgements
- If in doubt, don’t pull out! If in range, don’t lane change!

The control group watched the same video as used in Study 2 on the dangers of hands-free mobile phone conversations.

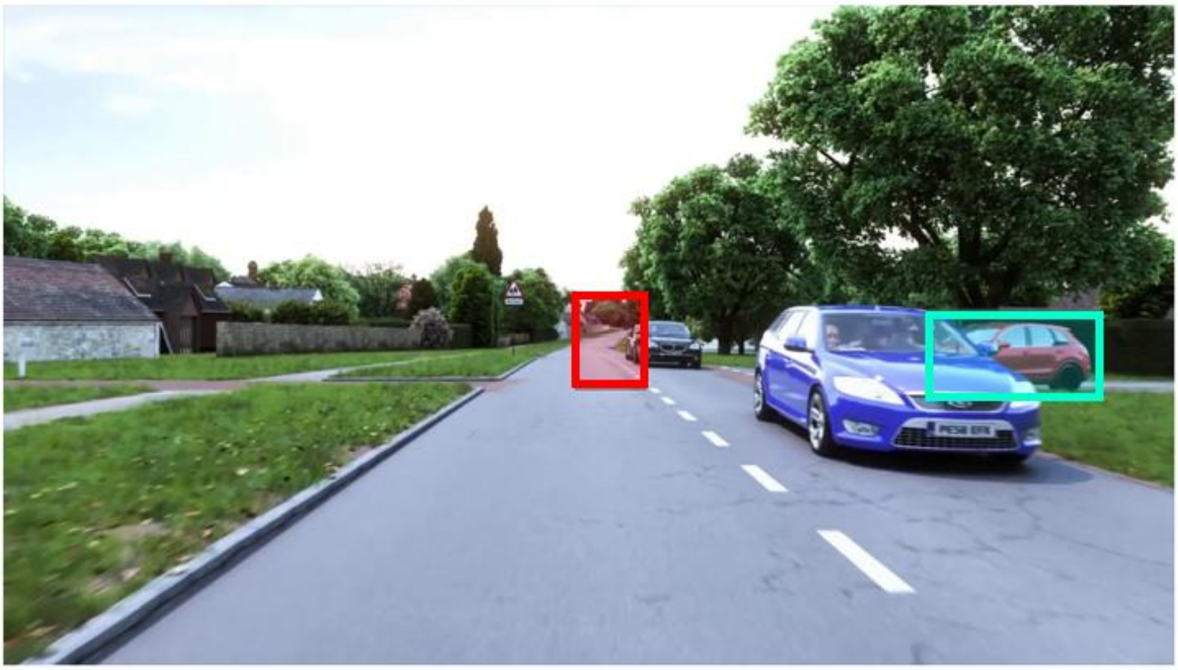

Figure C1. Car drivers in Study 3 were presented with clip M4 from Study 1 which shows the ego car preparing to turn right into a side road in-between queuing vehicles in the oncoming lane. On the final frame they were asked to click on up to three locations from which they might expect a hazard to develop. This image reflects the final frame with two Areas of Interest (AOIs) marked for (1) an *obvious potential hazard (a car in the side road) and (2) a location where a motorcycle hazard could appear from. Note the motorcycle hazard is not yet visible in the image, so any clicks in this area represent participants anticipation of a potential hazard rather than spotting an actual hazard. AOIs are not visible to participants and are just used for scoring.*

C3 Results

C3.1 Video evaluation

When asked their opinion on the intervention video, a very large majority of the sample agreed that the video had increased their understanding of why cars crash into motorcycles (92%; see Section 4.3, Figure 8). Large proportions of the participants reported the intention to use this information when driving in the future (88%), and that their empathy towards motorcyclist had also increased (88%).

Study 3 received fewer free text comments than the previous study, but again it was suggested that the video would be valuable to a wider audience: e.g., *"A great video for all drivers to watch and would be an important video to include when learning to drive."*

Given that these three questions were very similar to those asked of our motorcyclists in Study 2, it was possible to compare the ratings for these items across the two studies. We compared the participant groups' ratings separately for each question using Mann-Whitney U Tests. Motorcyclists and car drivers gave similar levels of agreement with the *understanding* item, and the *future behaviour* item, but a significant difference was noted with our groups' agreement that their *empathy* had increased ($U = 3576.50$, $p < .01$), with our car drivers showing greater agreement (see Figure C2).

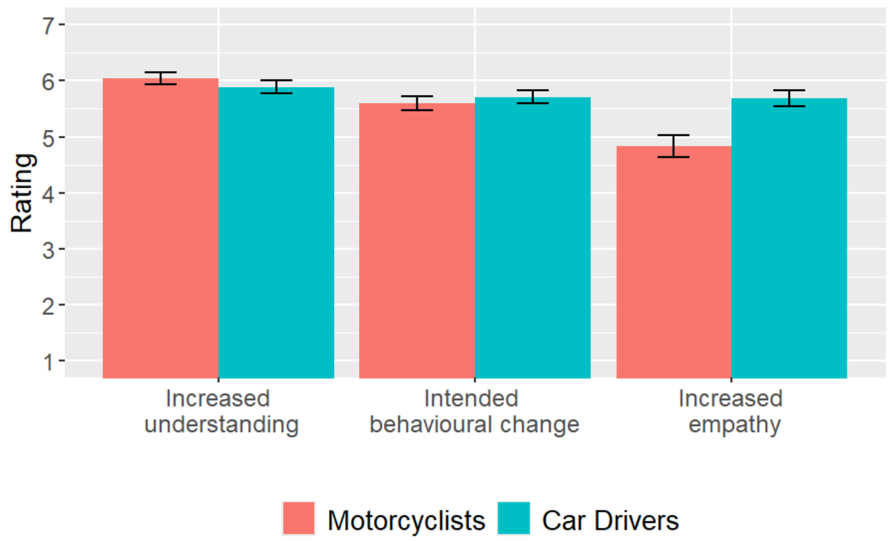

Figure C2. A comparison of ratings given by our motorcyclists (Study 2) and car drivers (Study 3) regarding their understanding of the causes of car-motorcycle collisions, whether the video would change their behaviour, and whether the intervention had increased their empathy to the other road user group.

C3.2 Perceived safety of motorcyclists and car drivers

A 2 x 2 x 2 mixed ANOVA compared the perceived safety ratings for the average motorcyclist and car driver across intervention condition, and pre/post data collection phase. Our car drivers rated other car drivers safer than motorcyclists, again demonstrating in-group bias (as shown by a main effect of road user, $F(1,146) = 74.09$, $p < .001$). There was also a main effect of the time at which the responses were collected (pre/post-intervention), $F(1,146) = 7.10$, $p < .01$, and an interaction between pre/post intervention and road user; $F(1,146) = 20.17$, $p < .001$. This suggests that all of our car driver participants felt that other car drivers were less safe when filling in the post-intervention questionnaire, regardless of whether they saw the intervention video or the control video (Table C1).

Table C1. Participant views on the general safety of car drivers and motorcyclists (ranging from 1 very unsafe, to 6 very safe) for both the intervention and control group, pre and post intervention.

	Intervention		Control	
	Pre	Post	Pre	Post
Perceived safety of motorcyclists	3.6	3.8	3.4	3.3
Perceived safety of car drivers	4.5	4.1	4.5	4.1

C3.3 The Blame Test

When considering the attribution of blame in near collisions, a similar pattern was found for the car drivers as for the motorcyclists (see Table C2). Near collisions were generally more attributed to the car driver than the motorcyclist, and, with a few exceptions, more to error than intention. A 2 x 2 ANOVA showed no differences between the intervention and control group and no significant change in attributed blame and cause after the intervention, although there was a trend to attribute the cause more to error after the intervention ($p = .07$).

Table C2. Car drivers' attribution of blame and cause in near collisions (ranging from 0 'motorcyclist completely to blame' to 100 'car driver completely to blame' and 0 'error of judgment' to 100 'intentional risky act') for both the intervention and control group, pre and post intervention.

	Intervention		Control	
	Pre	Post	Pre	Post
Attributed blame	71.9	74.0	71.6	71.4
Attributed cause	46.1	42.7	44.4	44.1

C3.4 Errors, Violations and Motorcyclist awareness

Cronbach's alphas for the three subscales of the questionnaire were 0.76, 0.77 and 0.59 (pre intervention) and 0.76, 0.82 and 0.57 (post intervention) for Errors, Violations and Motorcyclist awareness, respectively. We carried out 2 x 2 ANOVAs on each factor score. In the post-intervention phase, car drivers reported that they expected to make more errors in the future (Table C3). A significant interaction shows that this effect was stronger for the participants that had seen the intervention video. Furthermore, participants intend to make fewer violations in the future, and they expect to have greater awareness of motorcyclists.

Table C3. Average DBQ ratings (on a 6-point scale ranging from 'never 0' to 'nearly all the time 5') provided by our car drivers both before and after seeing the intervention or control video. ME1 is

'Main Effect 1' (Intervention vs. Control group), ME2 is 'Main Effect 2' (pre intervention vs post intervention). The final column gives the interaction for both factors.

	Intervention		Control		ME1	ME2	
	Pre	Post	Pre	Post	Int. vs. Con (*F*)	Pre vs. Post (*F*)	Interaction (*F*)
Errors (DBQ)	0.68	0.87	0.79	0.82	0.14	8.56**	4.28*
Violations (DBQ)	0.99	0.79	1.15	0.93	2.05	30.75***	0.03
Motorcyclist awareness	3.03	3.28	2.97	3.17	0.73	16.10***	0.11

Note: *<.05, **<.01, ***<.001

C3.5 Where's the hazard?

Participants were asked to click on up to three locations where they thought they were most likely to spot developing hazards in the final frame of a video where they are about to turn right (see Figure 8). Two *a priori* locations were defined as Areas of Interest (AOIs): a car waiting in a side road, and the location where a motorcycle would appear from (but was not yet visible). Regarding the motorcycle AOI, 49% of our intervention group clicked in this area, while only 24% of the control did so. An independent samples proportion test showed that this difference was significant, Z = 3.15, p < .01. There was no difference however in the proportion of the intervention and control groups that clicked on the car hazard (Z = 0.04), with exactly 61% of intervention group and 61% of the control group recognising this as a possible hazard (Figure C3).

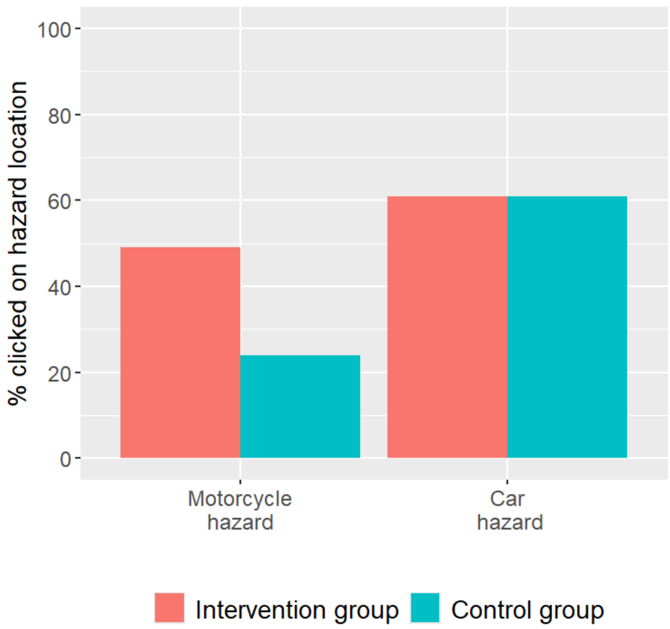

Figure C3. The percentage of our car driving sample who clicked on the motorcycle hazard or the car hazard in the final frame of clip M4, according to whether they were in the intervention group or the control group.